CHEMISTRY

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Neutron-Proton Exchange 1
Back Cover Picture
Stars Lined Up 8
Birth of Matter 9
Living Molecules
Structure by Specification 17
The Biological Enigma 18
Chemical Patents of the Month 21
Germany and the A-Bomb 24
Heisenberg's Account 25
What the Alsos Mission Learned 30
Hints for Your Lab
Useful Siphons 36
Siloxane Ring Measured 39
Anti-Histamine Drugs Fight Poisons 40
Fairy Jewels Synthesized 41
For the Home Lab
King Cotton 43
Young Scientists Compete 45
Editorial
On Teaching Science .....
Inside Front Cover

25¢

On Teaching Science

➤ Is IT BETTER to know a few things well, or to have a smattering of knowledge on many subjects? The choice is always facing teachers and those who decide on school curricula. The problem is no whit lessened by the speed with which scientific discoveries come popping out of research centers today. Not only are frontiers extended, the very props are knocked out from under old tried-and-true axioms on which the basic curricula are built. What is the teacher of general science or of elementary courses in the specialties to do?

The editors of CHEMISTRY feel very strongly that it is important for students even in elementary school to learn something of what is going on in the world of science today. It is doubtless necessary for beginners to learn the formula H_2O and to know the constitution of the atmosphere, but these were news a very long time ago and a good deal more has happened since then. New principles of energy, new understanding of the constitution of matter are constantly being added to the world's resources. Less and less well equipped for life in the modern world are pupils turned out of our schools without instruction in the principles of the scientific method and experience in doing experimental work with their own hands.

But they need also to know where the frontiers are on which the new work in science is being done. With the news-gathering resources of Science Service, the Institution for the Popularization of Science, behind it, CHEMISTRY brings its readers each month news of happenings on these frontiers. Alert teachers will cull from among these happenings those that touch tomorrow's lesson in their curricula, but they will also find time in the day's schedule for interpolation of new developments that won't get into their text-books for years to come.

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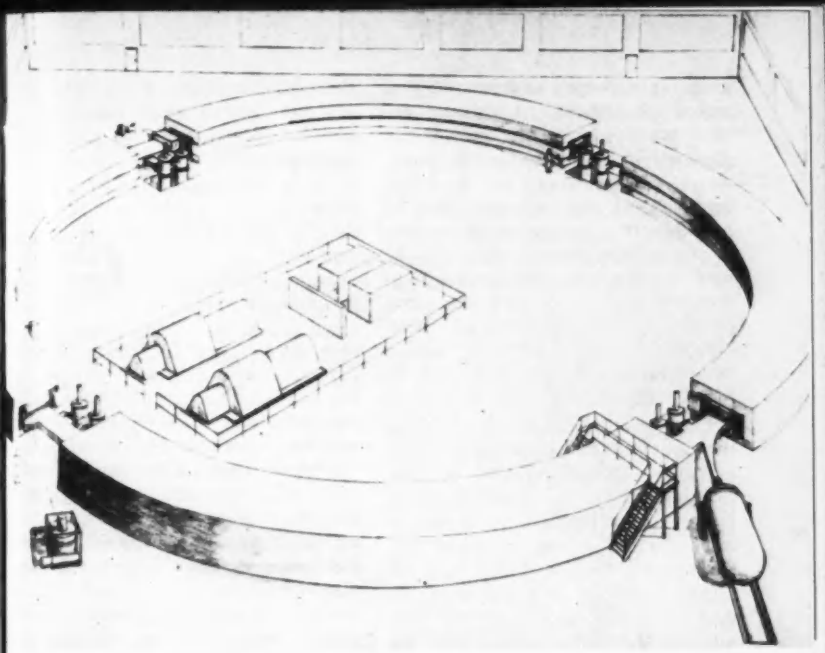

▶ THE BEVATRON, *according to its designer's drawing. This super-synchrocyclotron would carry us another giant's stride toward understanding the constitution of matter. Its ten billion electron volts promise even richer atomic disintegrations than those yet achieved.*

Neutron-Proton Exchange

by ERNEST O. LAWRENCE

Professor of Physics and Director of the Radiation Laboratory, University of California.

The following is Professor Lawrence's own condensation of the Silliman Lecture which he gave at Yale University at the celebration of the Hundredth Anniversary of its Sheffield Scientific School. Developments in atomic physics, Dr. Lawrence points out, have been and are continuing to be so rapid and so fundamental in character as to constitute truly a revolution in our understanding of the properties of matter.

▶ THE TOTAL ENERGY of a heavy atom like lead or uranium is about two hundred billion electron volts. Therefore, studies of energy transformations over a vast range are of import-

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ance for a deeper understanding of atomic phenomena. In ordinary nuclear reactions involving only a few nuclear particles, such as the radioactive transformations or the transmutation of one element into its neighbor, the energy changes are only a few million electron volts. To be sure, in cosmic ray investigations fragmentary evidence of transformations of very much higher values have been obtained, but the discovery of atomic fission marked the real beginning of high energy physics in the laboratory.

Long before the discovery of fission the vast extent of nuclear energies was of course appreciated—and likewise the importance of producing ever higher energy particles in the laboratory. And so, almost ten years ago plans were laid to build a giant cyclotron—one as large as practicable both financially[1] and otherwise—with the hope that such a great instrument would produce particles of the next higher energy range—hundreds rather than tens of millions of electron volts.

The actual construction of the great cyclotron, with magnet pole pieces 184 inches in diameter and weighing more than 4000 tons, was well started when the war necessarily interrupted the work.[2] Now from the standpoint of the purely scientific objective of getting on with the job of exploring farther into the realm of the atom, the war interruption might have been a serious loss—a delay of some five years. Actually, this delay turned out to be a blessing in disguise for the wide experience gained in the war effort by the scientists and engineers concerned, as well as many new technological developments, contributed greatly to the rapid and successful carrying out of the undertaking. Moreover, my colleague Dr. Edwin McMillan and independently V. Veksler in Russia meanwhile elucidated the principle of phase stability in the multiple acceleration of particles, embodied in the synchrotron. They pointed out with such clarity and so convincingly the way to higher energies that immediately after the war when the 184 inch program was resumed, the great instrument was redesigned, following their ideas, as a synchro-cyclotron, thereby more than doubling the power of the great accelerator. In the long view, therefore, and indeed in the light of new discoveries already made with these high energy particles, one may say that the delay of the war years will soon be made up, if it has not been already, by the more rapid progress in the accumulation of knowledge of atomic phenomena afforded by the availability of these higher energy particles in the laboratory.

The 184 inch synchro-cyclotron was turned on for the first time on November 1, 1946 and since that time has been producing deuterons of energies up to 200 million electron volts (Mev) and alpha particles up to 400 Mev. Since nowadays cyclotrons are in such wide use and, indeed, since so many synchro-cyclotrons are

[1] The undertaking was made possible by the generous support of the Rockefeller Foundation, the Research Corporation and the John and Mary Markle Foundation. Since the war the project has been supported by the Manhattan District and the Atomic Energy Commission.

[2] However, as is well known, the 184 inch cyclotron magnet was finished and served a useful purpose in the war effort in providing a splendid laboratory facility for the development of the calutron, i.e. the electro-magnetic process for the separation of the uranium isotopes.

planned or are under construction in various laboratories in this country and abroad, it is hardly necessary for me to undertake a general description of these machines here.

I should like now to give a brief account of some recent investigations that have been carried out with this most powerful of atom smashers—for, indeed, as we shall see, particles of hundreds of millions of electron volts do a very thorough job of breaking up even the heaviest of the elements!

Beam of Neutrons

When the 184 inch instrument was first turned on—indeed, during the first evening of operation last fall—a sharply defined beam of penetrating radiation was observed from the probe target in the cyclotron chamber. This extraordinarily interesting phenomenon of course was immediately the subject of some preliminary exploratory experiments. First of all, measurements of the penetrating power of the radiation were made by interposing various thicknesses of different materials in the path of the beam and observing the resulting reduction in intensity of the radiation as indicated by an ionization chamber. In this way Moyer, Hildebrand, Knable, Parmley and York found that it takes almost a foot of lead or concrete to reduce the radiation to one half—which indeed was something new in the laboratory!

Now, incidentally, apart from the scientific interest, the great penetrating power of these rays raised an immediate and urgent practical laboratory health problem, i.e. the provision of adequate radiation protection, for it was quite obvious that if the cyclotron were to be operated at full power for extended periods of time radiation shielding would have to be of massive proportions. In fact, on the basis of these and many later measurements it was determined that a concrete wall ten feet thick surrounding the cyclotron would be required for present levels of operation.[3]

These early observations also showed that the beam was made up largely of neutrons because lead was not as effective per unit mass as water or concrete in absorbing the radiation. Furthermore, reasonably good estimates of the energy of the neutrons could be made from the absorption coefficients and on this basis it was concluded that their average kinetic energy was of the order of 100 Mev. That the neutrons were of such high energy was also established during those first few days of operation of the cyclotron by Wilson Powell who placed a cloud chamber in the beam and observed great numbers of high energy recoil protons—many up to 100 Mev and a few in the neighborhood of 200 Mev.

And so, there could be no doubt as to the general character of the penetrating radiation. Here was truly a remarkable beam of high energy neutrons. As you can well imagine, before settling down to careful quantitative investigations, all concerned could not resist the urge of curiosity to carry out numerous quick and easy qualitative experiments to observe some of the properties of the radiation. For example, various substances

[3] It will doubtless be necessary to provide additional shielding sometime in the next year when the synchro-cyclotron is modified to produce 350 Mev protons and larger currents of deuterons.

were placed in the beam and a glimpse of some of the resulting nuclear reactions was obtained by the observation of the induced radioactivities. In this way, for instance, it was discovered that these high energy neutrons produce fission in a number of heavy elements including lead and bismuth. Another interesting and immediately useful observation was the production of radioactive carbon in graphite disks placed in the beam. This reaction, C^{12} (n, 2n) C^{11}, has a threshold of about 20 Mev and, therefore, serves as a convenient detector of high energy neutrons.[4]

By placing small discs of graphite across the beam and measuring the induced activity Helmholtz, McMillan and Sewell were able easily to map out the shape of the beam with considerable precision. They established that the neutron's rays were largely confined to an angular spread of about ten degrees in the direction of the 200 Mev deuterons striking the cyclotron target. This interesting result was not unexpected, as will be seen in the following.

Splitting the Deuteron

A deuteron consists of a neutron and a proton held together with a binding energy of about 2 Mev which is quite negligible in comparison to the kinetic energy of the deuterons striking the cyclotron target. Thus, in effect, the collision of a 200 Mev deuteron with an atomic nucleus would be much the same as the simultaneous collision of a 100 Mev neutron and a 100 Mev proton. In other words, the particles are held together so loosely in the deuteron that in a nuclear collision they are "on their own," so to speak. With these considerations in mind it is easy to see that sometimes in a collision, the proton might just scrape a nucleus while the neutron would miss it altogether, thus, in view of the loose binding, proceeding on its way in a straight line with the velocity it had at the instant of the collision. According to Professor R. Serber this is without doubt the process responsible for the observed beam of high energy neutrons.

Serber has worked out in detail the expected angular distribution of the neutron beam produced in this way. He pointed out that the neutron and proton in the deuteron in effect are not at rest relative to their center of gravity but have essentially a vibrational energy of some 2 Mev. In quantum mechanical terms one would say that the particles have "an intrinsic uncertainty in momentum" while in old-fashioned mechanical terms one would describe the deuteron as made of two heavy balls (neutron and proton) oscillating back and forth, held together by an elastic spring. Therefore, according to Serber, the expected distribution of velocities of the neutrons released on collision of the deuterons in the target would be given simply by adding their intrinsic velocity distribution to the velocity of the deuteron as a whole at the instant of collision. Calculations made in this way gave a theoretical distribution in excellent agreement with the experimental observations.

[4] Recent experiments indicate that well above the threshold value the induced radioactivity is insensitive to the energy of the neutrons and therefore proportional to the flux.

A Beam of Protons

Now, on the other hand, if in a nuclear collision the neutron of the deuteron just hits the nucleus, the proton will proceed on with the velocity it had at the instant of the impact and so a beam of protons would also be expected from the cyclotron target. Such charged particles, of course, would not proceed out from the target in a straight line like the neutrons, for they would be bent in the cyclotron magnetic field in circles half the diameter of the circles of the target deuterons. Thus, it was expected that protons would be observed bent to the central region of the cyclotron with energies in the range of 100 Mev and, needless to say, they were immediately observed.

The distribution in velocities of these protons, which we see according to Serber's ideas would be the same as for the neutrons, have recently been investigated by Chupp, Gardner and Taylor. They placed both photographic plates and disks of graphite with suitable shielding and diaphragms in the central region of the cyclotron and by counts of proton tracks in the plates, as well as by the radio-activity induced in the graphite by the reaction, C^{12} (p, pn) C^{11}, they obtained excellent agreement with Serber's theory.

And so, in this simplest case of atom splitting, theory and experiment are in excellent agreement. The phenomenon seems to be well understood.

Charge Exchange

I should like now to turn attention to the fundamental problem of the interaction of neutrons and protons. This is indeed a fundamental problem; for an understanding of this simplest of nuclear interactions must surely precede any general theory of nuclear matter.

Our present knowledge of nuclear forces is based very largely on the results of scattering experiments in the region of a few million electron volts.[5] However, some years ago Heisenberg proposed the idea of charge exchange in the interaction of protons and neutrons to explain the constancy of the binding energy of particles in light and heavy nuclei. The low energy scattering experiments gave no evidence one way or the other on the reality of such a charge exchange phenomenon, but, nevertheless, for some time now it has appeared probable that there may be two types of forces between the nuclear particles, (A) ordinary forces and (B) exchange forces.

The former are not unlike the forces in billiard ball collisions (or Rutherford scattering) and in a sense are understandable in terms of older ideas. But the exchange force is essentially a new concept. This force arises from a charge exchange phenomenon. To put the matter in concrete terms, the charge exchange hypothesis means that when a neutron and proton collide, even just barely "touch" each other, the protonic charge oscillates back and forth between the particles, so that when the particles move apart after the collision there is a likelihood that the neu-

[5] Professor Gregory Breit, for example, was the first to work out in detail the expected neutron proton scattering on the assumption of a finite range of the forces and also the analysis of proton proton scattering data in the range of a few million electron volts.

tron will have acquired the charge, therefore turning into a proton while the proton will have become a neutron.

The first truly convincing experimental evidence for the reality of this charge exchange between particles was given by the observation of Moyer and co-workers on transition effects in the walls of the ionization chambers used in the early measurements of the beam of high energy neutrons. They observed that the 100 Mev neutrons produced an abundance of correspondingly high energy recoil protons—quite in accord with the idea of the neutrons just touching protons in hydrogenous material and exchanging charge, thereby turning into high energy protons.

During the past few months this important matter has, needless to say, continued to be vigorously investigated. Thus, in order to gain more quantitative information, J. Hadley, C. E. Leith and H. York have observed the secondary protons from carbon and paraffin. They used proportional counters in quadruple coincidence as a proton detector and by suitable absorbers between the counters were able to select the higher energy particles. They found that the most probable direction of a high energy proton ejected from hydrogenous material by a 100 Mev neutron is in the forward direction which is in accord with the charge exchange idea.

These observations leave little doubt about the reality of the exchange process but they do not rule out the possibility of part of the interactions of these high energy neutrons and protons being of the ordinary billiard ball type. In random collisions of billiard balls the chance of a dead center knock on wherein the recoiling ball takes the whole energy of the cue ball is the same as one in which the cue ball just nicks the struck ball, the former proceeding on with little loss of energy and the latter moving sideways with relatively little energy. And so, the ordinary forces in neutron proton collisions would give rise to large numbers of recoil protons of low velocity moving almost at right angles to the neutron beam.

To look into this question Wilson Powell and Walter Hartsough have been using the cloud chamber which is best suited for the observation of low energy recoil particles. They find in confirmation of the observations of Hadley, Leith and York that there is a preponderance of high energy protons in the forward direction but in addition there are more low energy particles recoiling at large angles to the beam than would be expected on the basis of the charge exchange hypothesis.

Thus, we are led to the conclusion that both ordinary and exchange forces are necessary to describe the interaction of neutrons and protons. The experimental data along this line should soon provide much food for thought for our theoretical confreres!

Stars

One might infer from the foregoing that thus far the experimental observations into these higher energy levels of nuclear phenomena have been simple, orderly and understandable. Actually, of course, this is by no means the case as many new phenomena

have been observed which are not understood and await further investigation. To illustrate, there are the star disintegrations that have occasionally been observed in the cosmic rays and which now are a common feature of the cloud chamber pictures in our laboratory. Thus, one interesting example is that of a star disintegration wherein a 107 Mev neutron apparently hit an oxygen nucleus splitting it into four alpha particles, the neutron bouncing backwards with some 70 Mev energy. Such an event, according to our present understanding, is rather improbable. Is energy and momentum really conserved in such individual nuclear collisions? Some day perhaps we shall know the answer.

New Isotopes

Now if I may return to the early exploratory experiments of last fall. Professors Seaborg and Pearlman and their associates in chemistry were naturally curious as to the radioactive isotopes that would be produced by the high energy particles and so they made quick "spot checks" of the activities produced in various bombarded targets. They were confronted with a delightfully bewildering complex of radioactivities for it appeared that practically every chemical extraction showed several decay periods. With their extensive background and experience in the field, they were able to proceed rapidly in the identification of a large number of activities, some of which indicating that more than twenty nuclear particles had been knocked out. They soon found many new radio-active isotopes and in addition they were able to establish certain interesting general features of the nuclear reactions concerned.

It appears that more than one hundred new radioactive isotopes will eventually be identified; and apart from their intrinsic scientific interest, no doubt they will soon find their usefulness as tracers in other fields.

Heavy Elements Fissioned

It was natural also at an early date to bombard the heavy elements and determine whether imparting these higher energies to the nuclei would result in fission. Again, the observations were interesting to the point of bewilderment, as bombarding elements such as uranium, bismuth and lead produced not only what were evidently fission products but also a great many other radioisotopes over almost the whole periodic table. In consequence studies along this line are only well started. However, some interesting new features of the fission process have already emerged, especially the radically different distribution of the fission products. Again, we must look to the future and to our theoretical colleagues for the meaning of these interesting observations.

Higher Energy Particles

Thus, we see that the production in the laboratory of accelerated particles in the 100 Mev range has opened up a rich domain for investigation. Perhaps, therefore, we should now be content to devote all our attention to the experimental attack on the problems in this field. But the very richness of the atomic phenomena already apparent in the 100 Mev level surely beckons us on to greener pastures—the domain of billions of electron volts!

It is, therefore, understandable that as soon as the synchro-cyclotron was well launched on its operating career W. M. Brobeck, who was chiefly responsible for the engineering design of the great machine, should give some thought to the next step up the energy scale. It did not take him long to reach the conclusion that it was well within the realm of practical feasibility to construct a great proton accelerator for the 10 billion electron volt level. Indeed, he has already completed preliminary designs. Don't you think such a great accelerator will some day be built? I do.

On the Back Cover

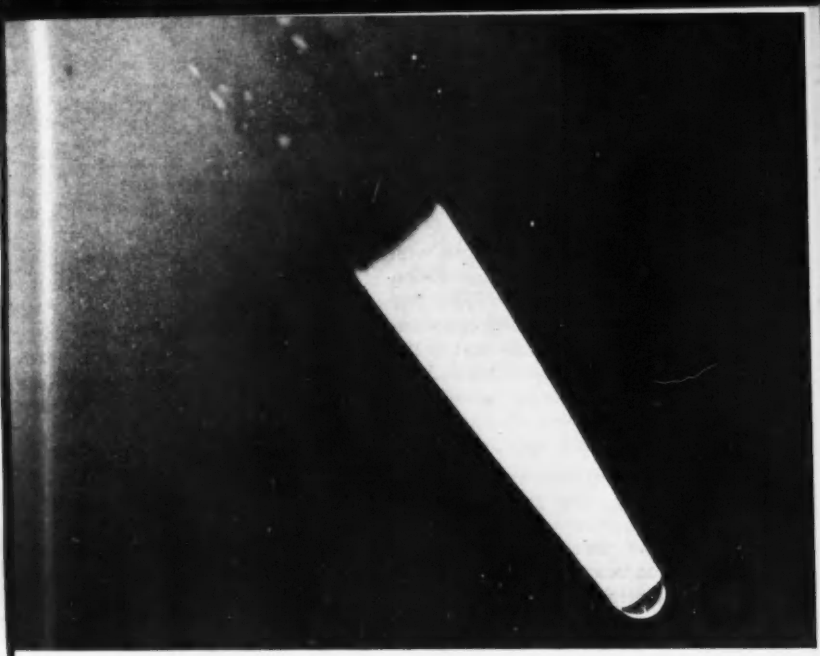
➤ STARS *are lined up in a row along this track of 100 Mev neutrons from the University of California's synchro-cyclotron. Between the stars, three short tracks show the first known record of where three neutrons turned into protons. Alpha particles and protons made the curving tracks, and the big curve swooping around the others came from a proton with 1.8 million electron volts of energy. The photograph was made by Dr. Wilson Powell.*

Uranium Boosts Yield From Seed

➤ RADIO-AGRICULTURE may be one of the developments of the atomic age that is now dawning. Hints of what may be coming are given in a report to the French Academy of Sciences by a nephew of Henri Becquerel, first man to observe radioactivity, the botanist Paul Becquerel. He states that treatment of seeds with solutions of salts of the radioactive elements greatly increases their yield as compared with control plants from untreated seeds.

Working with Mlle. Jacqueline Rousseau, M. Becquerel dipped peas in a one-to-10,000 solution of uranium nitrate. Vines grown from these out-yielded the controls by 10% on a dry-weight basis. When a growth-promoting hormone, phenylacetic acid, was added to the solution, the increased yield amounted to 27.5%. Similar treatment with a solution of manganese sulfate brought about a 19% dry-weight increase in yield.

Nearly $3,000,000,000 of new investments have been made in chemical industries in the United States during the war years to enable them to meet war needs.



▶ CURIOUS HYDROXIDE *(or is it curic?) takes its picture by its own visible light. The soft glow comes from the whole tube whose contents are kept in motion by vigorous boiling due to the energy constantly given off by its radio-activity.*

Birth of Matter

by GLENN T. SEABORG

In this address on Nuclear Transformations in the New High Energy Ranges, at a general assembly of the American Chemical Society in New York, the leader of the University of California, Berkeley, group studying the newest elements forecasts greater surprises soon to come.

▶ NUCLEAR SCIENCE is about to enter, and in fact has to some extent already entered, an important new phase in its development, namely, the area of ultra high energies. A limited entree into this region had already been permitted through observations with high energy cosmic rays, but these are of such low intensity as to limit seriously both the rate and the scope of progress which is possible. New ideas for design, together with new techniques for building, have led to prospects for the construction in the rather immediate future of a number of machines capable of accelerating

electrons and light positive ions to an energy region comparable with that of the most interesting of the cosmic rays.

This new phase is coming right on the heels of the amazing atomic energy development, which began with the discovery of the nuclear fission reaction in uranium by O. Hahn and F. Strassmann in 1939 and culminated in the successful attainment of the self-sustaining nuclear chain-reaction and the manufacture in quantity of the synthetic element plutonium for application to this purpose.

The nuclear chain-reaction is notable for the amount of energy which can be developed, since substantial quantities of fissionable material can be made to react and hence convert mass to energy. Since this is done through the medium of neutrons, another important feature is the intensity and total quantity of neutrons which have become available, leading to the transmutation of elements in macroscopic amounts and the production of radioactive isotopes on an heretofore undreamed of scale.

It is possible, and in fact quite probable, that the coming step into the very high energy region will lead to developments different in principle, in that it will go beyond the rearrangement of nuclear particles and enter the area of important insight into interactions between and the internal transformations of the fundamental nuclear particles themselves. Of course, even in the reactions which may be termed simple rearrangements of the fundamental constituents of nuclei, there will be important differences from previous observations which will be peculiar to the high energies involved.

While we are standing on the threshold of this new adventure, it is interesting to recall that the first induced nuclear transformation was observed by Rutherford less than thirty years ago. It was in 1919 at the famous Cavendish Laboratory in England that the bombardment of nitrogen with alpha-particles led to the cloud chamber observation of its transmutation to oxygen with the emission of protons. The source of alpha-particles in this case was one of the natural radioactive elements; and, in fact, it was not until more than a decade later, in 1932, that the first nuclear transmutation by totally artificial means was effected.

In this now famous classic experiment the British scientists J. D. Cockcroft and E. T. S. Walton accelerated protons to an energy of about 0.5 Mev by a direct fall through a potential difference of this magnitude. These protons were used to bombard the light element lithium. With the help of a cloud chamber the observation of the transmutation to two alpha-particles was made.

Although many of the first acceleration machines were of the type in which the total accelerating voltage was simply a high voltage applied once, such as the A. C. rectification and voltage multiplier units and the electrostatic generator, the principle of resonance acceleration in which a particle is subjected to a small accelerating field applied repeatedly over a long path, was being developed simultaneously. This found its most practical application in the magnetic

resonance accelerator or cyclotron developed by E. O. Lawrence at the University of California. This instrument was widely used in the 1930's and even the early models continue to yield important results.

The new machines all are characterized by the application of this resonance principle and in fact are also characterized by the application of less high voltage and more brain power than has been the case for the machines of the past.

The acceleration machines in the past, and also the chain-reacting piles, have given rise to bombarding particles with energies in the range of millions of electron volts, extending in a few cases into the region of tens of millions of electron volts. This energy region is, roughly speaking, just that of the nuclear binding energies, that is, the energy of binding of the elementary and small particles such as the neutrons, protons, and alpha-particles. The transformations have therefore been characterized by the addition or subtraction of one or two such particles leading to changes of something like one or two units in the atomic number and mass number of the bombarded material.

Although it is of course an arbitrary matter as to when we may consider ourselves to have entered a new energy range, it is generally considered that this is the case as we go into the region of hundreds of millions of electron volts. Although we have as one reason for this simply the historical fact that because of the course which the development of accelerators has taken, this energy region is being entered by making a large jump, of the order of a factor of ten or more, essentially all in one step, we have in addition a more scientific reason for singling out this area.

Mesotrons May Be Created

It seems reasonable to expect that it will be in this region that a first step in the inter-conversion of the elementary nuclear particles might take place. It may be possible with such energies to create mesotrons by artificial means for the first time. The mesotron, which has been observed and studied for about ten years as an important constituent of the cosmic rays, seems to have a rest mass of some 200 times that of the electron and hence the energy equivalent of its mass is about 100 Mev. Thus, it might be expected that with the acceleration of particles to a kinetic energy above 100 Mev, a transformation of kinetic energy might occur with its appearance as mass in the form of the mesotron.

Actually there are some experimental, together with a number of theoretical, considerations which lead to the view that this transformation, in order to occur with any significant probability, must involve the creation of a pair of mesotrons, one negatively and the other positively charged, and thus a minimum of 200 Mev of kinetic energy will be needed. This amount must be further increased in order to allow a sufficient amount of kinetic energy to go into the products and other participants of the

transformation so that the laws of conservation of momentum may be obeyed, and therefore, depending upon the particular reactions involved, the actual threshold may be somewhere above 200 Mev. (Known examples of transformations of the type in which elementary particles change their character or are created or destroyed are the processes of "pair production" in which positron-electron pairs are created from gamma-rays and "annihilation" in which gamma-rays are produced from positron-electron pairs.)

The mesotron plays an important role in the current theories of nuclear structure in that it is supposed to be intimately involved in the very fundamental interaction between neutrons and protons through which they are held together to create a nucleus. It is therefore hoped that their study as a result of their production in quantity by artificial means might give just the key which is needed to the fundamental understanding of the nucleaus of the atom.

Although the accelerators for the region of hundreds of millions of electron volts all use the resonance principle, there are a number of different methods by which this is done, and thus we have a number of devices such as the synchro-cyclotron, the betatron, the synchrotron, and the linear accelerator.

Before proceeding to a consideration of the actual results which have been attained through the use of the machines already in operation, it may be well to say a few words concerning the role which the chemist plays in this work. One of the most powerful means of determining a nuclear reaction is to identify chemically the radioactive products of the reaction. After the machines have effected the transmutations, the chemist goes to work, and he finds himself faced with some extremely interesting and challenging problems. It is his task to identify the atomic number of the transmutation products and his services here are practically indispensable. Usually there are a great number of radioactive isotopes of many elements produced during the irradiation of the target material.

Although a number of high energy accelerators are under construction, and it is beyond the scope of this discussion to try to survey this tremendous program from the standpoint of geographical distribution of the machines, at the present time only a couple of them are in actual operation. A number of results of interest have already been obtained through the use of the General Electric Company's betatron, which accelerates electrons to, and produces electromagnetic radiation of energy up to, 100 Mev, and the Berkeley 184-inch synchro-cyclotron or f.m. (frequency modulated) cyclotron, which produces deuterons and helium ions of energy about 200 and 400 Mev respectively.

Using the high energy x-rays from the General Electric's betatron, G. C. Baldwin and G. S. Klaiber have found reactions in which several neutrons or protons or combinations of neutrons and protons are ejected during the irradiation of a number of elements. As an example, we may cite the formation of the isotope Na^{24} from the irradiation of silicon (Si^{28}), a reaction in which three protons plus a

neutron seem to be ejected in arriving at the product. The observations so far seem to indicate that this electromagnetic radiation is insufficient in energy to effect the artificial creation of mesotrons.

Wide Range of Isotopes

The results with the 184-inch cyclotron have been spectacular. The bombardment of elements anywhere in the periodic table with 200 Mev deuterons or 400 Mev helium ions gives rise in each case to a tremendous number of radioactive product isotopes often extending over an atomic number range of ten or fifteen or twenty. For each of these elements in turn there are produced a number of radioactive isotopes so that in each bombardment the number of transmutation products is truly large. This leads to great complexity and a great strain is placed upon the chemical and physical measurements needed in order to unravel the results from each bombardment.

Already a number of results have been obtained of which it will be possible here to cite only a few. H. H. Hopkins and B. B. Cunningham have found among the many products from the bombardment of arsenic with 400 Mev helium ions the 37-minute Cl^{38} isotope. This corresponds to a reduction of 16 atomic number units, as the atomic number of chlorine is 17 while that of arsenic is 33; the corresponding decrease in mass units is 37. In another example, D. R. Miller and R. C. Thompson have found among the products of the irradiation of copper with 200 Mev deuterons and 400 Mev helium ions, in the manganese fraction alone, a range of radioactive isotopes from mass number 51 up to 56. M. Lindner and I. Perlman find that the bombardment of antimony (atomic number 51) with 200 Mev deuterons gives rise to radioactive isotopes extending from molybdenum (atomic number 42) to tellurium (atomic number 52) and the observations are still far from complete. These results, chosen quite at random, are meant to be only illustrative of the scope of the reactions which occur.

The occurrence of nuclear reactions involving the ejection of so many particles has raised a question as to the method for writing the reactions. The ordinary nomenclature is inadequate because in many cases the path by which the final product is obtained is indeterminate. For example, in the production of 46-minute Mn^{51} from helium ions on copper, it is not known whether the reaction is due primarily to the direct ejection of (assuming the isotope Cu^{65} is involved) 6 protons and 12 neutrons or 3 alpha-particles and 6 neutrons or 5 protons and 13 neutrons to form an Fe^{51} which goes to Mn^{51} by positron emission, etc.; probably a combination of several of these paths is involved. Consequently we have adopted the convention of writing the reaction Cu^{65} (a,6z18a) Mn^{51}, in which the z and a correspond to the loss in charge and mass units, respectively. According to this convention, for example, the above-mentioned production of Cl^{38} would be written As^{75}(a, 18z39a)Cl^{38}.

Spallation Reactions

It has also become convenient to have a term by which to refer to these reactions in order to distinguish them from ordinary nuclear reactions in which only one or two particles are ejected and from the nuclear fission reaction, and we have been using the term "spallation" reaction. Thus it can be seen that in the ultra high energy region the rearrangements of the constituents of nuclei lead to an astonishing richness of phenomena.

P. R. O'Connor has bombarded ordinary uranium with the 400 Mev helium ions and has found a tremendous number of radioactive products. These seem to extend, so far as can be deduced from the incomplete experiments, continuously from the region of uranium down to and through the normal region of the fission product isotopes and on below. Possibly the isotopes in the region between uranium and the rare earths are formed by the spallation reactions and the isotopes with atomic number below this are formed by the fission type of reaction.

Another observation of great interest is that of I. Perlman, R. H. Goeckerman, D. H. Templeton, and J. J. Howland who have observed that a number of elements well below the thorium-uranium region undergo the famous nuclear fission reaction when subjected to bombardments with very high energy particles.

They have observed that bismuth and lead undergo fission when irradiated with the 100 Mev neutrons which are produced in high yield when the 200 Mev deuterons impinge on any of the elements. The direct bombardment with 200 Mev deuterons leads to the observation of the fission reaction in bismuth, lead, and thallium; and with 400 Mev helium ions they have observed this interesting reaction with, in addition to these three elements, platinum (atomic number 78) and even so far down the periodic scale as tantalum (atomic number 73).

The threshold for this reaction, determined for the case of bismuth, is in the neighborhood of 50 Mev energy. For these elements the fission process is characterized by a distribution of the radioactive fission product isotopes leading to essentially one broad peak in the distribution-yield curve rather than the characteristic two peaks with a pronounced minimum between them in the curve for the fission products produced in the slow neutron irradiation of uranium and plutonium. The fission product distribution extends to lighter elements as might be expected in view of the lighter mass of these elements as compared with uranium and plutonium.

It should be emphasized that this observation of the fission reaction in relatively common elements such as lead opens no possibility for the production of self-sustaining nuclear chain reactions with these elements and there is no possibility for their employment as sources of atomic energy. One reason for this stems from the fact that any secondary emitted particles which might conceivably be eligible for perpetuating such a chain reaction have much too small an en-

ergy to be able to do so. However, this reaction serves to give us another look at the ways in which nuclear constituents can rearrange themselves and is of great interest from this point of view.

It seems highly probable that as a result of these new types of reactions the number of induced radioactivities, which already stands above five hundred, will be further increased by at least a hundred new isotopes. In the case of the spallation reactions many neutron deficient isotopes are formed thus making it possible to enter the region of the positron emitters in much the same way that the fission product isotopes have widened the area of the negative beta-particle emitters. It is probable that several of these new isotopes may become important as tracers.

New Particles with Higher Energies

The experiments with 200 Mev deuterons and 400 Mev helium ions have not yet led to the observation of the artificial production of mesotrons. It is planned to make certain fundamental changes in the 184-inch cyclotron next year which will make it possible to accelerate protons to about 350 Mev of energy, so we may look forward even that soon to a number of interesting new observations.

As mentioned above, the definition as to just what constitutes this new high energy range is an arbitrary one and even now there are plans which encompass its extension at the higher energy end into an area which might properly be classified as still another milepost beyond that of mesotron production.

When it should be possible to accelerate particles to the energy region of billions of electron volts, it may be possible to use this kinetic energy to synthesize neutrons and protons and thus truly to create matter from energy.

The rest mass energy equivalent of the neutron or proton is about one Bev (billion electron volts). Since these particles might be born in pairs, for example a pair consisting of a positive and a negative proton, and since a considerable fraction of the kinetic energy must be consumed in the process of momentum conservation according to the relativistic mechanics of the collision process, it follows that the threshold for such events will lie in the region of several Bev.

Another new process which might occur in the Bev energy region is that of the sudden production of many mesotrons in a single act, a phenomenon known to be brought about by single high energy cosmic ray particles and of considerable importance because of the light that it might throw on the whole theory of nuclear structure.

We will bring the discussion to an end by merely saying that highly advanced machines are under consideration, and even have entered the stage of preliminary design, for the acceleration of particles to these fantastic energies. Among these may be listed a machine conceived by W. M. Bro-

beck of the University of California and one being planned for inclusion among the group which is being built by the Brookhaven National Laboratory.

In these, both the frequency with which the accelerating potential is applied and the strength of the magnetic field is varied as the particle gains successive increments of energy while it repeatedly travels around a fixed orbit.

Apparently the prospects for entering this next energy region are good. Thus we may look forward to even more amazing developments, and not too far in the remote future, in the fields of nuclear science.

Bearing Metals in Machinery

➤ SELECTION of bearing materials in machinery has been discussed in a paper before the American Society for Metals by Arthur F. Underwood of General Motors Research Laboratories.

Hidden bearings in all machines with moving parts, running from simple linings in hubs of wheels in which axles revolve to complicated joints with complex movements, determine the life and usefulness of the device.

Formerly metals for bearings were judged by a few mechanical properties such as hardness, compressive strength and elongation. During the past ten years it has been recognized that individual uses have different requirements which include resistance to scoring and corrosion, compressive and fatigue strength, the structure of the bearing material and its ability to maintain form.

In any particular application some of these properties may be more important than in others. The best bearing material must be selected for the purpose it is to serve. The selection of the bearing material is always a compromise.

In his studies of various bearing materials, Mr. Underwood found an unusual relation between the score resistance, or anti-seizure characteristics, of individual metals and their place in the arrangement of chemical elements as given in the periodic table.

A regular pattern, he explained, will be observed where the recognized elements for bearings are always in the odd-numbered series. Further, the anti-seizure characteristics of the elements against steel improve with increase in the series number. Thus, aluminum, copper, zinc and silver, low in the series, have moderate anti-seizure characteristics; cadmium, indium and tin have better characteristics; and thallium and lead, higher up in the series, have excellent anti-seizure characteristics.

The corrosion of bearing materials was of no commercial importance until 1932, when high oil temperatures, highly treated lubricating oils and certain bearing materials occurred in automobiles. The problem, he said, has two distinct phases which are the oil and the metal. By properly compounding the oil, it can be made to retard oxidation with the accompanying development of acids that cause corrosion.

Molecular Forces May Bridge Gap Between Chemical and Life Phenomena

Living Molecules

Closer and closer scientists are pressing in on many sides upon the mystery of what distinguishes living from non-living matter. Somewhere in the realm of the large protein molecules lies the borderland, and life energy in all its manifold forms must there originate from forces that can be studied in inorganic material. The two following accounts of addresses recently given summarize two fruitful methods of attack on the problem of life at the molecular level. One approaches it from the inorganic side, from the behavior of enzymes through that of viruses. The other traces the reactions of genes, the units of heredity, which are themselves of molecular dimensions.

Structure by Specification

▶ WHETHER A DRUG will successfully combat an invading germ is largely dependent upon whether the drug can be more attractive to the germ than the living cell being attacked. This theory underlying many of the problems of chemical therapeutics was explained by Dr. Linus C. Pauling of the California Institute of Technology in the Silliman Lecture which he gave at Yale University's recent celebration of the hundredth anniversary of its Sheffield Scientific School.

Competition between drug and cell for the chance to combine with the germ is similar to many other types of specific action among physiologically active substances, such as antibody and antigen. Similar forces are probably also operative, according to Dr. Pauling, in the phenomena of self-duplication shown by viruses, genes and other biological entities. This is getting close to the explanation of the phenomenon of life.

But the great problem, in the opinion of the California scientist, is in understanding the structural basis of the substances which exhibit this physiological activity. Their molecules are subject to the same slight forces of electrical attraction, known as van der Waals forces, that have been studied in other fields. But these forces are ordinarily not specific. Any molecule is attracted with about the same force as any other molecule. Additional factors must be found to account for the unique attraction between certain substances which appears in many kinds of physiological activity.

Such factors may lie in the size and shape of the molecules involved. The antigen (germ factor) and the antibody (germ-fighting factor) are believed to interact as they do because they fit into each other in structure. A large portion of the surface of one can be brought into juxtaposition with the surface of the other molecule. Such closeness allows the weak forces op-

erating between them to create an effective bond. Thus the drug can counteract the germ.

The exciting thing about this scientific research is that the scientists have here the beginnings of a field of chemical kinetics which promises to allow them to design and then to build chemical substances that will block the activities of bacterial and virus growth.

"When once this problem has been solved," said Dr. Pauling, "and when it has become possible to determine in detail the molecular structure of the vectors of disease and of the constituents of the cells of the human body it will be possible to draw up the specifications of specific chemotherapeutic agents to protect the body against a specific danger, and then to proceed to synthesize the agent according to the specifications."

Closely related to this problem is the question of the nature of enzymes and catalysts. They, too, act in a way highly specific for the reactions they promote. Dr. Pauling believes that an enzyme has a structure closely similar to that found for antibodies, except that an intermediate compound is formed which has only temporary existence. The intermediate compound he calls the "activated complex."

To explain the fact that the living cell carries out many chemical reactions that do not occur when the reacting substances are simply mixed together, Dr. Pauling believes that the enzyme, in forming the activiated complex, strains and bends the structure of the material with which it first combines until it reaches the shape which will fit the other substance, whereupon combination of the two can take place.

If a substance can be found which is intermediate between the original substance and the product, in the way this activated complex is, it should be possible to make such a substance combine with the original material, for example with an enzyme essential for bacterial growth, and so inactivate it that growth of the bacteria is prevented. Promotion of this kind of chemical rivalry he looks upon as the coming field for work on chemical therapeutics, and he feels that understanding of its problems will come primarily through understanding the structure of organic molecules.

The Biological Enigma

➤ LIVING MATTER differs from nonliving in being able to vary the pattern by which it reproduces itself, according to an address by Dr. George Wells Beadle of the California Institute of Technology at Yale's Sheffield Scientific School centenary celebration. Speaking on the subject of "Genes and Biological Enigmas" he stated that, while the classic definition of the gene as the unit of inheritance is sufficient for discussion of the mechanism of inheritance, it is inadequate as soon as one asks "what is the function of the gene in development?"

"Genes are probably giant nucleoprotein molecules," said Dr. Beadle,

"which act in some template-like manner to direct the synthesis of specific proteins. If this view is correct, we may think of the sets of genes transmitted from one generation to the next through sperms and eggs as sets of master molecules which serve to initiate the formation of specific counterparts in the developing individuals of the next generation."

But the individual of the next generation differs from its parents in greater or less degree, and sometimes the difference is so wide that it starts a new variety or line whose characteristics are passed on to its offspring as a mutant strain. "The ability of a molecule or simple multimolecular unit to form replicas of itself in any of several alternative forms undoubtedly demands a considerable degree of complexity," stated Dr. Beadle. "It seems highly probable that the degree of complexity required to allow for mutation while still retaining the property of replica-formation is the only really important distinction between living and non-living systems."

Mutations among living forms occasionally occur spontaneously, and until about twenty years ago nothing was known about how they originate. But since Dr. H. J. Muller at that time discovered that X-ray irradiation speeds up the rate at which mutants in any species appear other workers have found that ultraviolet light will also produce this effect, as will certain chemicals. In general it is now known that any ionizing radiation will produce mutations. This knowledge brings the opportunity for experimental production of such new forms. "Pneumococcus type transformations," said Dr. Beadle, "which appear to be guided in specific ways by highly polymerized nucleic acids, may well represent the first success in transmuting genes in predetermined ways."

Looking back toward the beginnings of life on this planet Dr. Beadle quoted the opinions of scientists that there must have been a long period of inorganic evolution in which more and more complex carbon compounds were built up until there appeared one that by chance possessed the property of acting as a model in directing the synthesis of more units like itself. Such an organism must have been an ancestor of the infinitely more complex present-day organisms. "Once such living systems became numerous," said Dr. Beadle, "it is easy in principle, though not always in detail, to visualize the processes by which the subsequent evolution of highly elaborated and specialized organisms such as exist today could have taken place."

The constitution and behavior of such hypothetical "protogenes" would probably have been of the same order as those of the genes of present-day higher organisms, and not very different from those of enzymes and viruses at the present time, even though viruses may be degenerative forms of once more independent organisms. By studying such comparatively simple forms, better understanding of general life processes may be reached.

But, said Dr. Beadle, "just as the underlying basis of normal differentiation stands high on the list of enigmas pertaining to living systems, so the cause of the abnormal differentiation characteristic of tumors re-

mains one of modern medicine's major unsolved problems. Great sums of money are being spent, and an impressive array of talent is being brought to focus on the problem. Nevertheless, progress is discouragingly slow. Few really promising leads have turned up. One of the theories that has gradually gained favor is that tumorous growths are the result of somatic gene mutation. Possibly one of the reasons why this theory has been looked on with so little favor in certain quarters is that it offers so little hope for a 'cancer cure.' We can increase gene mutation frequencies in many ways but there appears to be little immediate hope of decreasing them."

Further knowledge of the structure and properties of the genes, the irreducible units of living systems, was held out by Dr. Beadle as the key to many important problems of biology.

New Refining Process

➤ NEW NON-MINERAL oil products, improved quality and larger supplies of known oil products and major economies in the refining of vegetable, animal and marine oils and fats are claimed for a new process of refining.

Some of the achievements and forecasts for the new process are: New oil products from various types of animal fats; new sources of vitamins, particularly A and D; colorless, odorless fractional oils from such sources as soybeans and cottonseed; and linseed oil substitutes from low quality marine oils such as sardine, herring and menhaden.

The process, named the Solexol process by the M. W. Kellogg Co., applies a non-chemical principle to the refining of fats or oils. It is a liquid extraction and fractionation process using a special grade of propane as a non-toxic, non-corrosive, stable solvent. The solvent circulates continuously through a closed system in intimate contact with the oil or fat that is being refined. Cost of the solvent is less than five cents a gallon, with little of it lost in the system.

Operating at temperatures well below the boiling point of water, the process is instrumented with automatic control devices so that two men can operate the average-sized plant.

Several plants are now under construction to utilize the new refining process, while engineering is reported underway on several others.

New products are expected to result from the separation of the animal and vegetable oils into their segments without impairing their natural qualities with odors or colors.

By making possible the refining of low vitamin potency sources of oils such as sardine, herring and menhaden, more commercial vitamins are expected to be available. With high potency vitamin sources, including the livers of the soupfin shark, halibut and cod, the new process promises increased concentrations of the oils.

Processing cotton seed and soybeans has produced high quality industrial and edible oil products at reduced costs from the conventional refining processes.

Oil from the low quality marine oils is expected to supply an important substitute for linseed oil in paint.

Both Metallic and Organic Compounds Play New Roles

Chemical Patents of the Month

By writing to the Commissioner of Patents, Washington 25, D. C. complete specifications for any patent may be ordered by number for 25 cents each. Send coin or money order, not stamps.

▶ AMMONIUM SULFAMATE, one of the sensational weed-killing chemicals born of the wartime emergency, is manufactured in a more direct and economical way under a new procedure on which U. S. patent 2,426,420 has been issued to Ernest J. Tauch of Cleveland Heights, Ohio.

The method is an improvement on an earlier German process which was largely a failure. Theoretically, ammonium sulfamate should result directly when ammonia and sulfur trioxide are mixed. In the German process this was attempted with both compounds in the gaseous state, but the reaction produced unwanted ammonium imidodisulfonate instead. By mixing an excess of liquid anhydrous ammonia with sulfur trioxide in either liquid or solid form, Mr. Tauch has been able to obtain the desired compound. Care must be taken, he states, to make the mixing rapid and thorough, and to get rid of the heat evolved in the reaction. Evaporation of the excess ammonia helps accomplish this.

Patent rights are assigned to E. I. du Pont de Nemours and Company, sole manufacturers of ammonium sulfamate, who market it under the trade-name "Ammate."

Gold and Copper in Solder

▶ GOLD and copper are alloyed to make a special-purpose solder by Dr. Richard B. Nelson, a General Electric Company research physicist. Preferred proportions are 37.5% gold, 62.5% copper. The solder is used on such difficult metals as copper and iron-nickel-cobalt alloys. Also, because its expansion characteristics are close to those of glass, it is well suited for making high-vacuum seals between glass and metals. Patent 2,426,467 has been granted on Mr. Nelson's solder.

Two New Jato Motors

▶ TWO NEW rocket-like devices for jet-assisted take-offs are covered by patents 2,426,526 and 2,426,537, both assigned to the Aero-jet Engineering Corporation of Azusa, Calif. The first, developed by Hans Rutishauser, R. C. Brumfield and Fritz Zwicky, is on a casing made in two separable parts to facilitate reloading with a solid propellant charge. The second, invented by W. E. Van Dorn, which utilizes liquid fuel like long-range rockets, is streamlined, has means for parachute landings, and a cushioned nose to soften the bump when it comes down.

Improved Oil Cracking

▶ AN IMPROVEMENT in petroleum cracking is the basis for the claim on which patent 2,426,848 was issued to

Malcolm H. Tuttle of New Rochelle, N. Y., assignor to Max B. Miller and Company, Inc. In this process the heavy oils are cracked by passage through a bed of incandescent granular coke, kept hot by combustion from below, and at the same time continuously renewed by formation of new petroleum coke on top. It thus makes the process continuous, obviating shutdowns needed to clear retort walls of hard crust.

Newest Freon

➤ A NEW AND economical process for the production of a member of the Freon family of chemicals is the subject of patent 2,426,637, issued to a du Pont chemist, W. S. Murray of Wilmington, Del. The particular compound sought is high in fluorine, with the formula $CClF_3$. It is made by contacting two other related compounds, which contain more chlorine, with a catalyst under suitable heat and pressure conditions. Freons are used in electric refrigerators, as solvents, and in other ways.

Lead-TMP Gasoline

➤ GASOLINE has had something new added, to improve its performance even over that of the now familiar leaded fuels. The something is either trimethyl phosphate or trimethyl phosphite; U. S. patent 2,427,173 has been issued to Dr. Lloyd L. Withrow of Detroit on his formula.

Gasoline was originally leaded, Dr. Withrow explains, to reduce knocking, which is an effect of premature ignition of the fuel mixture under high-compression conditions. But the lead itself, becoming part of the ignition-chamber deposit, helps to set off a different type of unsparked ignition, termed "autoignition." Addition of the methyl-phosphorus compounds checks this, without reducing the anti-knock properties of the tetraethyl lead addition.

Patent rights have been assigned to the General Motors Corporation.

Better "Stickum" from Corn

➤ A CHEMICAL INVENTION for which botanical research blazed the trail is represented in patent 2,427,328 granted to H. H. Schopmeyer and Dr. G. E. Felton of Hammond, Ind., assignors to the American Maize-Products Company.

During the war, plant breeders worked hard on waxy endosperm maize, a kind of corn intended to replace the tapioca formerly imported as raw material for commercial adhesives, including the familiar "stickum" on stamps and envelope flaps. The newly patented process "pregelatinizes" a paste made of this corn by injecting jets of steam, that simultaneously heat it and bring its water content to the desired level. Then it is finished by flash drying.

Salvaging Pickling Liquor

➤ SALVAGING spent pickling liquor, a perennial problem in the steel industry, is undertaken anew by Frank A. Elzi, of Pueblo, Colo., who has assigned his patent, 2,427,555, to the Colorado Fuel and Iron Corporation.

Pickling liquor is dilute sulfuric acid, applied to raw steel and iron to remove oxide scale. After a time its principal content has become ferrous sulfate, with some residual free acid. In his process, Mr. Elzi first converts all this residual acid into sulfate by adding scrap iron. Then he bubbles ammonia gas, a waste pro-

duct of coke ovens, through the liquid. This captures the sulfate group, becoming ammonium sulfate, valuable as fertilizer. The iron is precipitated as ferric hydroxide, convertible into industrial rouge.

Thorium Protects Mirrors

➤ ALUMINUM, front-silvered on mirror surfaces in optical instruments, is commonly protected by giving it an exceedingly thin coating of some other element or compound, less easily scratched. A tougher, more resistant coating than any at present in use is claimed as basis for patent 2,427,592, assigned to the Radio Corporation of America by Glenn L. Dimmick of Indianapolis. It is thorium oxyfluoride, deposited out of vapor phase in a vacuum in the customary fashion, then baked in an oven for several hours for final hardening.

Alloy Welding

➤ AN AUTOMATIC machine for welding resistant alloys onto the surface of cast-steel tubing intended for use under chemically or thermally difficult conditions is covered by patent 2,427,350, granted to O. R. Carpenter of Barberton, Ohio, and Howard J. Kerr of Westfield, N. J.

Insect-Proof Package

➤ PATENT 2,427,647 was issued to Hans W. Vahlteich of Edgewater, N. J., on a multiple-layered insect-proof food package in which either the outer or a middle layer is impregnated with DDT.

Nicotinamide

➤ AN IMPROVED process for making nicotinamide, sometimes clinically preferable to straight nicotinic acid (niacin), is offered by Paul W. Garbo of Brooklyn for patent 2,427,400. Melted nicotinic acid is cascaded or sprayed into an atmosphere of ammonia at proper temperature to produce a combining reaction.

Corundum Jewels

➤ CORUNDUM is produced in jewel form, for bearings and other industrial purposes, by a process on which patent 2,427,454 has been granted to John Allen Heany of New Haven. The necessary ingredients are kneaded into a dough-like paste with water, molded to shape, then treated at a temperature of from 1500 to 1800 degrees Centigrade for from one to four hours.

Weed-Killers May Harm Grain

➤ PLANT-KILLING chemicals that eradicate weeds, yet have no effect on grains and other members of the grass family when applied to their leaves, can seriously harm or even kill them if they reach their roots. This has been determined by experiments at the biological-warfare laboratory at Camp Detrick, Md., which are reported by Dr. W. B. Ennis, Jr.

Leaves of oat seedlings growing in flowerpots were dipped in a solution of O-isopropyl N-phenyl carbamate. No harm resulted. But when the same chemical was applied to the soil, the plants died. Weaker doses permitted the plants to survive, but when the oats ripened they were weighed, and it was found that the treated plants' yield was materially smaller than that of the controls. Field tests confirmed the conclusions.

Here for Comparison's Sake Are Both Sides of the Story

Germany and the A-Bomb

➤ GERMANY's scientific prestige suffered a supreme defeat when during the war German scientists, among them Otto Hahn who discovered uranium fission in December 1938, failed to make an atomic bomb. Now, over two years after Hiroshima, the story can be told of what was happening under Hitler while America was achieving the bomb.

The fact is that the Germans wanted to make an atomic bomb, but they never found out how. They were working on a uranium machine, or what we call an atomic pile. They didn't quite succeed in getting a self-sustaining chain reaction in the pile, as the Americans did in December 1942, although they nearly did just before American troops reached Haigerloch in April 1945.

In a colorful story of the U. S. Mission that captured German atomic scientists and apparatus, (the book ALSOS, *Shuman,* $3.50), Prof. Samuel A. Goudsmit of Northwestern University writes that the German scientists failed to understand the difference between the uranium machine they tried to build and the bomb itself. They thought the pile would be the bomb.

In his foreword, Prof. Goudsmit writes: "The plain fact is that the Germans were nowhere near getting the secret of the atom bomb. Months after our scientists had established, beyond the shadow of a doubt, the feasibility of the atom bomb, the Germans were still only talking about the 'uranium problem,' and the possibility of constructing a 'uranium machine.' They did not know how to produce plutonium. They knew only, perhaps with typical German arrogance, that if they could not make an atom bomb, nobody else could, either, and so they need not be unduly worried. That arrogance received a terrible jolt the day our atom bomb fell on Hiroshima."

It was on August 6, 1945, at dinner time, that the German scientists first heard news of the Hiroshima blast, Prof. Goudsmit relates in his book. "The initial reaction of the German physicists . . . was one of utter incredulity," he writes. " 'Impossible,' they said. 'It can't be an atomic bomb,' one of their number said, 'it's probably propaganda, just as it was in Germany.'

"That being settled, the German scientists were able to finish their dinner in peace and even partially digest it. But at nine o'clock came the detailed news broadcast. The impact on the scientists was shattering. . . . At one stroke, all their self-confidence was gone, and the belief in their own scientific superiority gave way to an intense feeling of despair and futility."

It was shortly afterward that some of the younger men in the German group hit upon a "brilliant rationalization" of their failure. "This, then, was to be the new theme song of

German science," Prof. Goudsmit writes: "Germany worked on the uranium problem for peaceful uses only; the allies, for purposes of destruction."

Prof. Werner Heisenberg, leading German physicist whose theoretical contributions rank with those of Einstein, was a leader in German atomic research. Prof. Goudsmit tells how Heisenberg openly fought Nazi excesses, defended Einstein's theory of relativity which was to Hitler "Jewish" physics. But Heisenberg's "extreme nationalism led him astray during the war" and he was one of the German scientists taken into custody by the American ALSOS mission when it moved into Germany on the heels of our troops.

Prof. Heisenberg himself in a paper appearing in the German journal *Die Naturwissenschaften* a few weeks ago gives his version of why the atomic bomb was not a German achievement. The following extract is from a translation of this paper, published in the London journal, *Nature*.

Heisenberg's Account

"THE MOST IMPORTANT progress in the uranium project was achieved during the year 1941. Initially some negative results were recorded. Thus, the enrichment of U(235) by the Clausius-Dickel thermal diffusion method, using gaseous UF_6, proved impossible (Fleischmann, Harteck and Groth). The absorption cross-section for neutrons of the highest purity electrographite was determined in the Kaiser Wilhelm Institute at Heidelberg (Bothe and Jensen), and the behaviour of pure carbon estimated from the results. It appeared, according to the information then available, that even the purest possible carbon was unsuitable for the construction of a uranium pile; whereas, as is well known, carbon has been used in the United States with complete success. Whether the Heidelberg conclusions were falsified by insufficient consideration of the chemical impurities present in commercial graphite (for example, hydrogen or nitrogen), or by deficiencies in the theory, can scarcely be assessed for the moment. In any event, the Heidelberg experiments on graphite and beryllium (Fünfer and Bothe) made it clear, in connexion with later experiments in the Berlin-Dahlem Institute, that both pure carbon and pure beryllium were highly suitable for use as an outer cover for a uranium pile, inasmuch as their low absorption cross-section and high reflecting power restrict the spread of the neutrons escaping from the pile, thus reducing its minimum dimensions.

"In the summer of 1941, 150 litres of heavy water were available for the first experiments on a neutron-injected pile built up of uranium and heavy water (Döpel and Heisenberg, Leipzig). The uranium and heavy water were arranged in alternate spherical layers with the neutron source at the centre. The oxide U_3O_8 which was first employed produced only a slight increase in the number of escaping neutrons, which could scarcely be considered a clear proof that $k > 1$. The use of pure uranium metal, however, gave such a decided improvement

that no further doubt of a real increase in the number of neutrons ($k > 1$) was possible (about February or March 1942). Here then was the proof that the technical utilization of atomic energy was possible, and that the mere enlargement of the Leipzig apparatus must furnish an energy-producing uranium pile.

"At the same time, important administrative changes were taking place. At a meeting held in the building of the Reichsforschungsrat in Berlin, on February 26, 1942, the results to date were reported to the Minister of Education, Rust, and several directors of war research. The uranium project was transferred from the Heereswaffenamt to the control of the Reichsforschungsrat; and the then president of the Physikalisch-Technische Reichsanstalt, Esau, was made responsible for the project. On June 6, 1942, there was a second meeting at Harnack House in Berlin, when the results of the uranium project were reported to Speer, as Minister for War Production, and to the armament staff.

Uranium Pile Possible

"The facts reported were as follows: definite proof had been obtained that the technical utilization of atomic energy in a uranium pile was possible. Moreover, it was to be expected on theoretical grounds that an explosive for atomic bombs could be produced in such a pile. Investigation of the technical sides of the atomic bomb problem—for example, of the so-called critical size—was, however, not undertaken. More weight was given to the fact that the energy developed in a uranium pile could be used as a prime mover, since this aim appeared to be capable of achievement more easily and with less outlay. As to the separation of the uranium isotopes, no method was known which would have allowed of the production of an atomic explosive without an enormous and therefore impossible technical equipment. Incidentally, the use of protoactinium as an atomic explosive was also considered, since its nucleus is fissionable by neutrons with energies down to 10^5 eV., with the consequent possibility of a fast chain reaction. It was, however, considered to be impracticable to prepare the necessary quantities of the element.

On a Small Scale

"Following this meeting, which was decisive for the future of the project, Speer ruled that the work was to go forward as before on a comparatively small scale. Thus the only goal attainable was the development of a uranium pile producing energy as a prime mover—in fact, future work was directed entirely towards this one aim. Again during the summer of 1942, discussions were held with heat experts on the technical problems of heat transfer from the uranium to the working material (that is, water or steam). Technical experts from the Navy attended the meeting with a view to the possible use of a uranium power unit in warships. The Kaiser Wilhelm Institut für Physik was restored to the Kaiser Wilhelm Gesellschaft, with the author as director. In preparation for investigations on the larger uranium piles planned in the Institute, a spacious underground laboratory was added (Wirtz).

"About this time, however, the strain of the War on the already

overloaded German industry was making itself felt. Uranium and uranium slugs were produced in such small quantities that deliveries were late and the larger-scale experiments were repeatedly postponed. Nevertheless, important progress was made. As early as 1941, a research group at the Heereswaffenamt (Diebner, Pose, Czulius) had made measurements on a large pile built up as a lattice of uranium cubes in a paraffin matrix; the subsequent theoretical investigation (Höcker) demonstrated that the lattice construction could in certain circumstances show advantages over the layer arrangement. An experiment made by this group with a model pile of uranium cubes in D_2O ice did, in fact, yield a larger increase in the number of neutrons than the Leipzig pile. In a later experiment, using 500 litres of heavy water, a further increase in the number of neutrons was recorded. Measurements made in the Heidelberg Institute with a small model pile defined the relation between the increase in the number of neutrons on one hand, and the thickness of the layers on the other; while experiments undertaken by Bothe and Flammersfeld at Heidelberg, and by Stetter and Lintner in Vienna, threw new light on the fission processes occurring in U(238). A theoretical investigation by Bothe stressed the importance of the 'stopping distance' *(Bremslänge)* for the minimum size of a self-sustaining pile.

"In preparation for further experiments with larger quantities of heavy water and uranium metal, the Kaiser Wilhelm Institut für Physik in Berlin began a study of the effect of graphite and water as an outer cover for the pile. Resonance absorption in uranium had been studied by Volz and Haxel and by Sauerwein. Further, the absorption cross-sections of a series of different substances were measured by Ramm, as well as by Volz and Haxel at the Berlin Technical High School. As regards the question of thermal stabilization of the energy production resulting from the temperature broadening of the resonance lines, experiments by Sauerwein and Ramm with the Berlin-Dahlem high-voltage plant were significant.

"In the spring of 1943, the Norsk Hydro electrolytic plant was put out of action in a Commando raid. Its reconstruction was begun, but finally the responsible army command in Norway reported that effective protection of the plant, particularly against air raids, was impossible. In October 1943 the plant was completely destroyed in a heavy air raid. Nevertheless, about two tons of heavy water were available in Germany at the time: a quantity which, according to our calculations, was just enough for the construction of an energy-producing pile. The Reichsforschungsrat had made no effective provision for the construction of a new heavy water factory in Germany, and the pilot plant at I. G. Leuna made slow progress. It was proving, in fact, barely possible, in view of air raids and the overall strain on German production, to undertake such big building projects. The production of uranium slugs came to a temporary standstill after the raids on Frankfurt in 1944.

"Even then, some progress was achieved by the Harteck-Groth-Beyerle group. As early as 1942, this group had succeeded in developing

an ultracentrifuge for the enrichment of the isotope U(235). It was planned to use uranium enriched with the rare isotope in the construction of improved uranium piles, possibly in conjunction with ordinary water. At about this time, the direction of the uranium project was transferred from Esau to Gerlach. Gerlach had taken over the physics section of the Reichsforschungsrat, and he strove to promote more particularly the scientific side of the uranium problem; and at that, not only the physical, but also the medical aspect. In connection with the medical applications, the construction of a low-temperature pile, in liquid carbon dioxide, was undertaken on Harteck's suggestion. Such a pile, even of small dimensions, could be expected to yield profitable amounts of radioactive elements for tracer research, in view of the decreased absorption of the resonance lines at low temperatures.

A Model Pile

"In the winter of 1943-44, a model pile of 1.5 tons of heavy water and about the same weight of uranium plates was constructed in the Dahlem air-raid shelter through the co-operative efforts of the Kaiser Wilhelm Institutes for Physics in Berlin and Heidelberg (Wirtz, Fischer, Bopp, P. Jensen, Ritter). The number of neutrons injected from the internal source was multiplied by the factor 3, a performance approaching considerably nearer to what we called the *Labilitätspunkt,* at which the ratio k increases beyond the limit and at which the uranium pile begins to radiate independently of the neutron source and thus to produce energy. The relation between neutron increase and layer thickness fulfilled expectations. Further, the stopping distances of the fission neutrons in carbon and heavy water were redetermined (Wirtz) and the former inexact measurements considerably improved. These experiments were made in the air-raid shelter of the Institute during the heaviest raids on Berlin, and were naturally to some extent hindered by the raids. On February 15, 1944, the Kaiser Wilhelm Institut für Chemie received a direct hit. In the meantime, the Kaiser Wilhelm Institut für Physik had been partly evacuated to Hechingen. On the instructions of Gerlach, a cellar cut out of the solid rock, situated in the village of Haigerloch, was equipped for the rebuilding of the uranium pile. It was not until February 1945, however, that the greater part of the necessary material (about 1.5 tons of heavy water, 1.5 tons of uranium, 10 tons of graphite, cadmium for the regulating rods, etc.) was finally assembled at Haigerloch, and a new pile, this time built up of uranium cubes in heavy water, with an outer cover of graphite, constructed (Wirtz, Fischer, Bopp, Jensen, Ritter). A branch of the Reichsforschungsrat at Stadtilm was allotted the remaining quantity of heavy water and a great part of the available uranium. The Haigerloch pile yielded a sevenfold neutron increase. The material available at Haigerloch, however, was just insufficient to attain $k = \infty$. A relatively small amount of uranium would in all probability have sufficed; but it was no longer possible to obtain it, since transport from Berlin or Stadtilm could no longer reach Hechingen. On April 22, Haigerloch was occupied.

and the material confiscated by the Americans.

"When we compare the German work reported here with the corresponding Anglo-American effort, so far as it has been made known, then the beginning of 1942 seems to be the turning point. Up to that time, both sides were dealing predominantly with the scientific problem as to whether nuclear energy could be utilized at all, and what fundamental methods had to be employed to that end. Both sides had arrived almost simultaneously at very similar results, if one excludes the field of isotope separation, in which the Anglo-Americans had made much greater progress. Furthermore, in the United States far more attention had been given to laying the groundwork for subsequent full-scale development of the uranium project; so that the first self-supporting pile was functioning as early as December 1942.

Could Not Have Succeeded

"It remained to determine the technical sequel to these results. In the United States, the final decision was taken to go for the production of atomic bombs, with an outlay that must have amounted to a considerable fraction of the total American war expenditure; in Germany an attempt was made to solve the problem of the prime mover driven by nuclear energy, with an outlay of perhaps a thousandth part of the American. We have often been asked, not only by Germans but also by Britons and Americans, why Germany made no attempt to produce atomic bombs. The simplest answer one can give to this question is this: because the project could not have succeeded under German war conditions. It could not have succeeded on technical grounds alone: for even in America, with its much greater resources in scientific men, technicians and industrial potential, and with an economy undisturbed by enemy action, the bomb was not ready until after conclusion of the war with Germany. In particular, a German atomic bomb project could not have succeeded because of the military situation. In 1942, German industry was already stretched to the limit, the German Army had suffered serious reverses in Russia in the winter of 1941-42, and enemy air superiority was beginning to make itself felt. The immediate production of armaments could be robbed neither of personnel nor of raw materials, nor could the enormous plants required have been effectively protected against air attack. Finally—and this is a most important fact — the undertaking could not even be initiated against the psychological background of the men responsible for German war policy. These men expected an early decision of the War, even in 1942; and any major project which did not promise quick returns was specifically forbidden. To obtain the necessary support, the experts would have been obliged to promise early results, knowing that these promises could not be kept. Faced with this situation, the experts did not attempt to advocate with the supreme command a great industrial effort for the production of atomic bombs.

"From the very beginning, German physicists had consciously striven to keep control of the project, and had used their influence as experts to direct the work into the channels

which have been mapped in the foregoing report. In the upshot they were spared the decision as to whether or not they should aim at producing atomic bombs. The circumstances shaping policy in the critical year of 1942 guided their work automatically towards the problem of the utilization of nuclear energy in prime movers. To a German physicist, this task seemed important enough. The mere possibility of solving the problem had been rendered possible by the discovery of the German scientific workers Hahn and Strassman; and so we could feel satisfied with the hope that the important technical developments, with a peace-time application, which must eventually grow out of their discovery, would likewise find their beginnings in Germany, and in due course bear fruit there."

What the Alsos Mission Learned

➤ "The war was not ending so quickly as the Nazis had hoped and, accordingly, in June, 1942, the Reich's Research Council was taken out of the hands of the Ministry of Education and placed directly under Goering. Six months later Schumann's Army Ordnance checked out of the picture and their chief experimenter, Diebner, together with all equipment and materials, was turned over to Goering's outfit.

"On the whole, the change was beneficial to the German uranium work. It meant unification, even though rival groups now had to work together. But especially the fact that Goering was now the boss of the show—if in title only—boosted the morale of the scientists. The brilliant success of the Air Force's research under Goering was taken to be a good omen. But Mentzel was still there in administrative charge of the Reich's Research Council and Esau remained in charge of nuclear and general physics—and they had grown no less incompetent because they were now working under Goering. Esau simply was not acceptable to the nuclear physicists.

"Meanwhile research on the uranium pile was being conducted in several places. The principal work was done at an excellently equipped, underground, bomb-proof laboratory at the Kaiser Wilhelm Institute for Physics in Berlin. Experiments were also being carried on at the University of Leipzig and, under Diebner, at an Army proving ground near Berlin. Important contributions were also made at the Kaiser Wilhelm Institute for Physics at Heidelberg.

"But the time came when it was impossible to work any longer in the cities because of the frequent Allied bombings. Hahn's Institute for Physical Chemistry in Berlin had already been bombed. The Institute for Physics was still intact, but it was decided to evacuate the principal laboratory to somewhere in the country where the chance of bombings was remote. Diebner moved to a schoolhouse in a little town in Thuringia. Heisenberg and his group moved to the village of Hechingen near the Hohenzollern castle where they occupied a wing of a textile factory, while their pile laboratory was set up in a cave in the near-by town of Haigerloch. Many

other laboratories were moved from the cities to this region of southern Germany. Hahn's Institute was in the near-by town of Tailfingen. The primitive setup of these new quarters didn't make the work any easier; nevertheless they continued to work on with a fair degree of optimism.

"In Hamburg, Harteck had supervised most of the work on heavy water and the separation of Uranium 235. There, some small-scale centrifuge isotope separations were attempted. Now these operations also were moved, and ended up in a wing of a parachute-silk factory in the little town of Celle, near Hannover.

"It was not until the beginning of 1944 that the scientists, with the secret help of Speer, Minister of War Production, succeeded in squeezing out Esau, who became the boss of radar and radio research. The Speer ministry had always shown an interest in the uranium problem. It had the last word in assigning priorities, without which the procurement of materials was impossible. Speer's support gave some important phases of the project the highest priority—such as the manufacture of uranium metal by the Auer Company. Esau was replaced by a real, first-class physicist, Walther Gerlach, of the University of Munich. An able experimenter, Gerlach was also experienced in dealing with government and Army officials, as well as with prima donna scientists. He was acceptable to all; even his Gestapo record was favorable, in spite of some earlier clashes. He did much to bring unity among the various groups whose members had thus far been rivals.

"Gerlach was at first reluctant to take on his new job, but no doubt felt it was his patriotic duty to do so. To a friend, who pointed out that the war was already lost for Germany, he said: 'We must keep what we have got. We must let our physicists continue their work in their laboratories and at the universities. We must give them the best equipment and instruments and above all save as much as we can of men and material for after the defeat. That will be my task and my duty, nothing else.' With this in mind, he prevented physicists from being drafted into active service, even into the 'Volkssturm,' which was supposed to make a last-ditch stand.

"In spite of administrative changes and the increased importance given to the uranium project, it remained comparatively insignificant. The total number of scientists working on uranium and closely allied problems was less than one hundred. They lacked the equipment necessary for important preliminary and basic laboratory measurements. For instance, they complained in their reports that there were no cyclotrons in Germany, whereas the United States had twenty of these important machines. They had had to go to Paris to work with Joliot's cyclotron. Although half a dozen machines were planned or under construction in Germany, only the one in Heidelberg, in the physics section of the Kaiser Wilhelm Institute for Medical Research, was completed and used before the end of the war.

"Such was the background of German research. How far did they get toward a solution of the uranium problem?

"They knew, of course, the possibility of a U-235 bomb, but they considered it practically impossible to separate pure U-235. One can hardly blame them for this. Perhaps only in America could one have visualized and realized an Oak Ridge, where pure U-235 was produced by the huge combined efforts of science, engineering, industry, and the Army. No such vision was apparent among the German scientists and certainly no such gigantic combination of all forces working on all cylinders.

No Plutonium

"Furthermore, the Germans never thought of using plutonium in the bomb, which enormously simplified the problem. The existence and probable properties of plutonium, though still unnamed, had been mentioned in scientific literature before the war, and in a few German secret reports, but they overlooked the practical phase of this side of the problem completely.

"In fact, the whole German idea of the bomb was quite different from ours and more primitive in conception. They thought that it might eventually be possible to construct a pile in which the chain reaction went so fast that it would produce an explosion. Their bomb, that is, was merely an explosive pile and would have proved a fizz compared to the real bomb.

"It was this misconception which made the Germans believe that an energy-producing pile was the first problem to tackle. In our case it was the other way around. We discovered that it was easier to make an atomic bomb than an atomic power plant.

"Our lingering belief in the supremacy of German science makes it hard for us to accept the fact that the German physicists could have failed so utterly. There are even scientists among us who still refuse to believe that their German contemporaries could have made such blunders. For these, it is necessary to quote a few German statements which prove the facts beyond all possible doubt.

"When the greatest of modern atomic physicists, Niels Bohr, fled Denmark in the fall of 1943, he reported that the Germans were merely thinking of an explosive pile. At that time we thought this meant simply that they had succeeded in keeping their real aims secret, even from a scientist as wise as Bohr.

"But a secret Gestapo summary dated May of the same year, states:

'There are two technical applications of uranium fission.

'1. The *Uranium Engine* can be used as a motor if one succeeds in controlling the fission of atomic nuclei within certain limits.

'2. The *Uranium Bomb* can be realized if one succeeds in bombarding uranium nuclei suddenly with neutrons. The neutrons released in the fission should not be allowed to escape, but their too-large initial speed must be slowed down sufficiently so that they will again produce further fissions. The process propagates itself like an avalanche.

'Mathematical computations based on foreign data have shown that processes 1 and 2 are technically certainly possible.'

"In a recent press dispatch Otto

Hahn is quoted as stating: 'We knew that [plutonium] must exist, but we did not succeed in producing this substance.'

"Heisenberg, according to the Associated Press, said that he advised the German authorities that 'atomic explosives could be produced either by the separation of uranium isotopes or by building a uranium pile.' This is a typically careful statement, which makes our scientists believe that he meant 'of course' to use the pile to produce plutonium. He never thought of it; the pile itself was supposed to be the bomb.

Necessary Quantity Large

"In November, 1944, an engineer of the SS, Himmler's Elite Guard, who had some contact with physicists in Vienna, complained to his superiors that Germany did not work hard enough on an atom bomb. In a short letter he tried to describe the advantages of such a missile. Gerlach was asked to formulate an answer for the SS officials and he states, in a top secret letter, that the ideas of the SS engineer were in many points closely related to the German uranium project, but, as he wrote:

'Unfortunately the *technical* ideas are not correct. According to all available experimental and theoretical investigations, which agree completely on this precise point, it is not possible to obtain the violent increase in nuclear fission with small amounts of material. I can assure you that we have approached just this problem again and again from different viewpoints. Not even fundamental laboratory measurements on this effect can be performed with small quantities; one needs, on the contrary, amounts of at least two tons or more, which is one of the causes why the uranium problem is so difficult. . . .'

"And thus the German physicists worked earnestly on the construction of a uranium pile. If that succeeded, they thought, the bomb would be only one step further. At any rate a pile might produce an energy source which would enormously increase Germany's economic power and war potential, and this work would at least secure for them their world supremacy in science.

"Success did not come easily. The progress was slow. The rival groups in the early days of the Uranium Club, the many moves to avoid bombing, the primitive facilities in the evacuated laboratories, the shortage of 'heavy water' after the destruction of the Norwegian plant, all hampered research. But the principal handicap was probably the lack of vision of Heisenberg, whose ideas seem to have dominated most of the experiments.

Report Disregarded

"For instance, there was one German physicist, Fritz Houtermans, who came closest to the idea of plutonium. In a secret report, written as far back as 1941, he pointed out that a pile might produce new materials, heavier than uranium, which would probably have the same explosive properties. Moreover, he stated that such new elements could probably be separated by reasonably simple chemical methods. But although his report was reprinted twice, no one seemed to take any notice of it. Hout-

ermans was not in the good graces of the Heisenberg clique; since he did not belong to the inner circle, he did not have to be taken seriously.

"Heisenberg and Diebner at first worked independently. Diebner's work was, of course, considered inferior by Heisenberg and his elite entourage. But it so happened that Diebner had thought of a much better construction of a uranium pile than Heisenberg. This must have been quite a shock to the Heisenberg group and forced them into closer co-operation with their rivals.

No Chain Reaction

"The German physicists never got so far as to have a working pile, but thanks to Diebner's success they came nearer to it. Early in 1945, very near the end of the war in Europe, they believed that their preliminary measurements had finally proved conclusively that a chain-reacting pile was possible.

"In February, 1945, panic broke loose in Berlin because of the approach of the Red Army. Gerlach, pale, excited and depressed, had come to Berlin to remove the stock of 'heavy water' and other materials for the uranium project and to take it to Heisenberg in Southern Germany. Gerlach was very much afraid that the precious 'heavy water' might be destroyed. He hated to let it escape from his supervision and gave Heisenberg strict instruction to safeguard it and the uranium metal. Part of the uranium he stored in his Thüringen laboratory. Gerlach was excited, because of the recent progress that had been made. To a visitor who asked what Heisenberg was going to do with all this material he answered, 'Perhaps business. Do you know that the U-engine works?" The visitor, who was quite upset by this statement, became inquisitive. Gerlach told him that he had just had word from Heisenberg that the last measurements were in full agreement with the theory. Here the visitor interrupted and said, 'But there is quite a difference between a machine ready for work and just the knowledge how it would work *if* it were ready. It usually takes about ten years to put the conception of a scientific idea into technical use,' and he mentioned several examples.

" 'Yes, I know that,' answered Gerlach, 'but in this case it may be possible to produce the reaction in six or seven months.'

" 'But,' the visitor interrupted again, 'under present circumstances that means at least a year. The Russians will be in Berlin long before that and all of Germany will soon be occupied by Allied troops. Perhaps there will be a last stand in the Berchtesgaden region, but that means merely a few more weeks until the final fumigation of the Nazis in their caverns. You don't really expect that the work will be continued in Hitler's mountain stronghold?'

"Gerlach became more and more uneasy. He cursed the Nazis and the whole war. He wished the Allies would stay where they were so that he could finish the uranium pile. 'This is a great triumph,' he said. 'Think of the implications. Gasoline and radium will be obsolete.' Getting more and more excited, he added: 'And it is not too late. A wise gov-

ernment, conscious of its responsibilities, could perhaps demand better peace conditions, because we, the Germans, know something of extreme importance which the others don't. But,' he added sadly, 'we have a government which is neither wise nor has ever had any feeling of responsibility.'

"Rather cruelly, Gerlach's visitor retorted: 'Suppose someone really should be so stupid as to use this for negotiations with the other side. What do you think they would do? Either kill all the physicists, so that they couldn't do any more harm, or keep them behind barbed wire until they have told all they know about the uranium engine or the bomb. But even this may not be necessary. Have you considered that maybe American, British, or Russian scientists know as much or perhaps more about it than you do?'

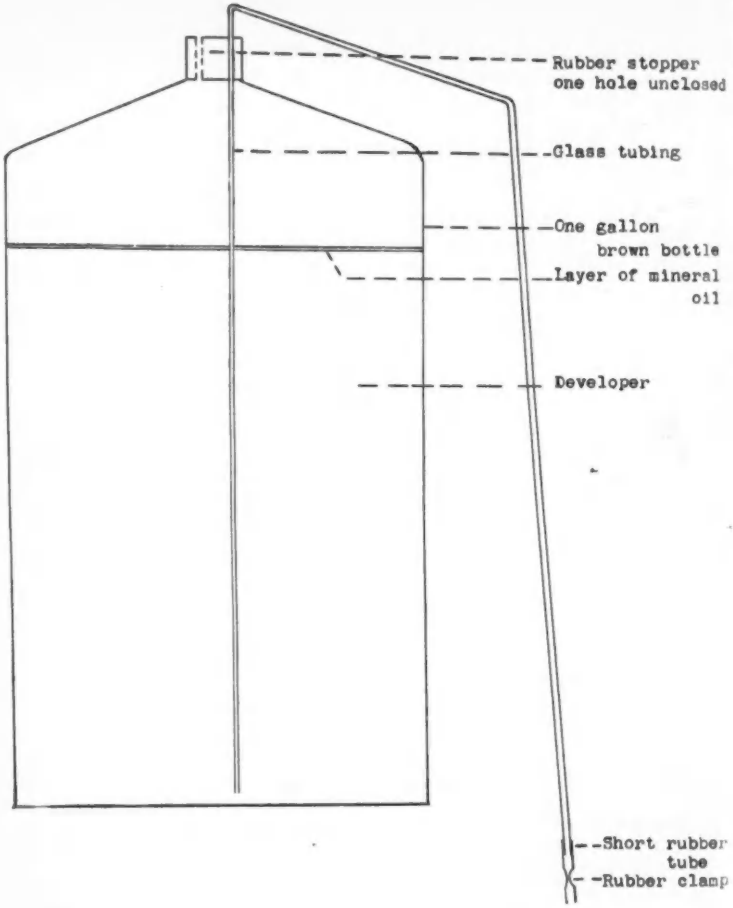
"It is significant that the conversation was reported to the Alsos Mission *before* Hiroshima, before the world knew that the Allies had succeeded in making an atomic bomb. Gerlach's visitor was the German scientist P. Rosbaud, scientific editor of the famous publishing house of Springer. Rosbaud, originally an Austrian, is among the few who kept their integrity throughout the Nazi regime and the war. His personality and deep understanding gave him the friendship and confidence of all true scientists who came in contact with him and they were many. Everyone knew of his outspoken anti-Nazi feelings and that he tried to keep in contact with Allied colleagues via neutral countries. He was living proof that it was possible to continue unmolested without giving in to the Nazi pressure. He never gave the Nazi salute, never displayed a Nazi flag. There were fortunately a few more among the scientists who acted similarly, notably the physicist Von Laue. These and a few other cases belie the contention that it was absolutely necessary to follow the Nazis in order to be able to live."

Glassworkers' Eyes Protected

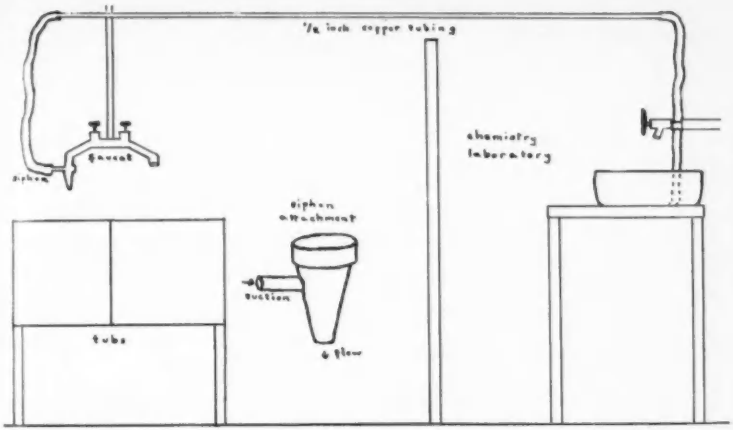
▶ GLASSWORKERS, fusing glass in sodium flares, are enabled to see work otherwise hidden by the yellow flame by means of new eyeglasses announced by the American Optical Company at Southbridge, Mass.

The lenses of the new eyeglasses contain standard optical glass to which is added a small quantity of a rare metal, didymium. Lenses made of this special glass absorb 90% of the yellow sodium flare of the fusing flame which is caused by the burning of sodium, one of the ingredients of glass. They permit the worker to look through the opaque yellow light emitted and see his work clearly. They protect workers also from the headaches that usually accompany extended work with sodium flames.

Although actually a mixture of two metals, praseodymium and neodymium, the old name for the unseparated blend of the twin elements is retained in practice as didymium.



➤ How Mr. Welkos *contrives to fill and empty his bottle of developer without allowing it to come in contact with the oxygen in the air.*



➤ How Mr. Eaton *gets waste water to the drain in the next room.*

Hints for Your Lab:

Useful Siphons

Two readers have found ways to put the principle of the siphon to work to their advantage. The results sound like magic. Mr. Welkos draws a solution out of a bottle that is never opened; Mr. Eaton empties a jar into a sink in the next room. Here is how they manage it.

➤ Our high school Photo Club has its own dark room. The club members furnish their own film and photographic papers and the school furnishes the chemicals. The developer, in order to be used most economically, is mixed in one-gallon lots. However, if it is not used within a short time the hydroquinone in it will oxidize, even though the bottle is kept tightly stoppered.

We have solved this problem by floating approximately 200 cc. of pure mineral oil on the surface of the developer solution, and siphoning out the developer as it is needed. When new developer solution is needed it can be made up and poured directly into the stock bottle. No chemical reaction takes place between the oil and the developing agent. The same bottle and supply of oil may be used for years, provided the photographers do not allow their supply of developer to fall so low in the bottle that oil is removed by the siphon.

Hilton W. Welkos

* * *

➤ I have a moderately well-equipped laboratory in my cellar, with gas,

electricity and running water, but I had no drain. I had to use a bucket to catch the waste, and this led to a number of headaches including a slopped-up floor, no matter how careful I tried to be. To put a sink in would have been a major operation in work, also on the pocketbook.

To eliminate all this, I ran 50 ft. of ½-inch copper tubing to the wash tubs in the other end of the cellar and there I installed a water siphon three inches long, one inch in diameter. One like it can be bought at any reliable store that sells chemical equipment. Mine cost a dollar and a half.

The siphon can be screwed to the faucet like a garden hose. The suction arm is attached to the copper line by a short piece of plastic or rubber tubing. A piece of tubing at the other end of the copper tube hangs into the sink or bucket. When this is to be emptied, turn on the faucet at the tub. The waste water from the laboratory will be siphoned off through the copper tube very quickly.

The same siphon can be used for decanting liquid from precipitates and also for suction filtering. It gives a 30-inch vacuum, which is very efficient.

THOMAS EATON, JR.

To contributorss:

Laboratory set-ups which you have found useful may be passed on to other workers through this column.

Please type directions, double-spaced, on one side of the paper. Make directions terse but very clear. Warn your readers of any unusual difficulties you have found likely to arise. In describing preparations, state approximate yield.

Drawings are not required, but if you want to send them please do them professionally in India ink, or else do them in pencil without shading. Drawings should be on separate sheets of paper, and your name and address should be on each sheet of paper you send.

Address "Hints Editor,"
CHEMISTRY, 1719 N St., N. W.,
Washington 6, D. C.

Tensile Strength of Cotton Yarn Increased

► COTTON YARNS are given additional strength by the application of a new chemical, members of the American Association of Textile Chemists and Colorists were told at a meeting in Winston-Salem, N. C., recently by Dr. Donald H. Powers of Monsanto Chemical Company. The tensile strength of the yarn may be increased up to 40%, he declared.

The improvement is effected through mill applications of a special submicroscopic colloidal silica called Syton, he said. This chemical was developed by the company to make sheer stockings run-resistant and to take the shine off serge. When applied to cotton sliver in concentrations of 1% to 3%, the inter-fiber friction is increased and it was possible to increase the tensile strength as stated, and to decrease the twist as much as 40%.

Molecular Pattern Mapped For First Member of New Series

Siloxane Ring Measured

► NEW AND IMPORTANT polymers and plastics have been developed from a class of compounds known as the "siloxanes." The fundamental structure of this group of substances is a chain of alternating silicon and oxygen atoms, with two organic groups linked to each silicon. For contrast, a similar skeleton, wherein the silicons are bound to four, rather than two oxygen atoms, while the oxygen atoms are each bound to two silicons, as above, is nothing but the brittle common sand.

The siloxanes form straight or branched chains and rings. Two Cornell University chemists, Miss E. H. Weller and Dr. S. H. Bauer determined the structure of the simplest member of the ring series, and reported their findings at the recent meeting of the American Chemical Society. Their compound is known as *hexamethylcyclotrisiloxane*. Three silicon and three oxygen atoms joined alternately to form a ring; six methyl groups, each consisting of one carbon and three hydrogen atoms, are bound to the silicon atoms, making a sort of fence around the outside.

The Cornell scientists found that the silicon oxygen ring is flat, and measured the distances between the atoms in the ring, and between the silicons and their protecting methyl groups. Structurally, this cyclotrisiloxane rings is analogous to the paraaldehyde ring in organic chemistry. In the latter, three carbons and three oxygen atoms join hands alternately to form a puckered six membered ring.

Whether the siloxane ring will form the variety of compounds obtainable from the corresponding carbon ring is not yet known, but the Cornell chemists say the chemical they measured is only the first of a long series analogous to the carbon polymers that are the marvelous new fibers, textiles and plastics we now use every day.

Already silicon has mimicked carbon to form a whole family of silicon chain compounds—vapors that waterproof, liquids that lubricate and solids with remarkable properties. Now silicon promises to rival carbon in the making of ring compounds of great future promise.

Atomic Energy Train in Britain

► BRITAIN will have an atomic energy exhibition train which will tour the nation from November to April, much the way the American Freedom Train is barnstorming America.

The British Atomic Scientists Association planned this public education activity in connection with local atomic energy weeks during which the causes of war will be studied.

New Hayfever Remedies
Possible Poison Antidotes

Anti-Histamine Drugs Fight Poisons

➤ THE POSSIBILITY that the new hayfever medicines, benadryl, pyribenzamine, neoantergan and others, may act as antidotes to certain poisons has been suggested by the French scientist who discovered the mother substances of these modern hayfever medicines.

He is Dr. Daniel Bovet, now at the Instituto Superiore di Sanita in Rome, but for about 20 years the only pharmacologist at the Pasteur Institute in Paris. While there he not only discovered the first of the anti-histamine chemicals which relieve hayfever and hives, but with Drs. E. Trefonel and F. Mitti discovered that sulfanilamide is the active part of the original German prontosil. The whole development of the sulfa drugs is based on this discovery.

At the New York Academy of Sciences conference on allergy he reported the new possibilities of the hayfever remedies he fathered.

The South American Indian arrow poison, curare, and certain other poisons and some purgatives, he reported, appear to act in the body by liberating histamine. The new hayfever drugs are noticeably antagonistic to the action of these poisons as well as to histamine. Study of the poisons mentioned, he pointed out, has opened up an interesting and so far little explored field.

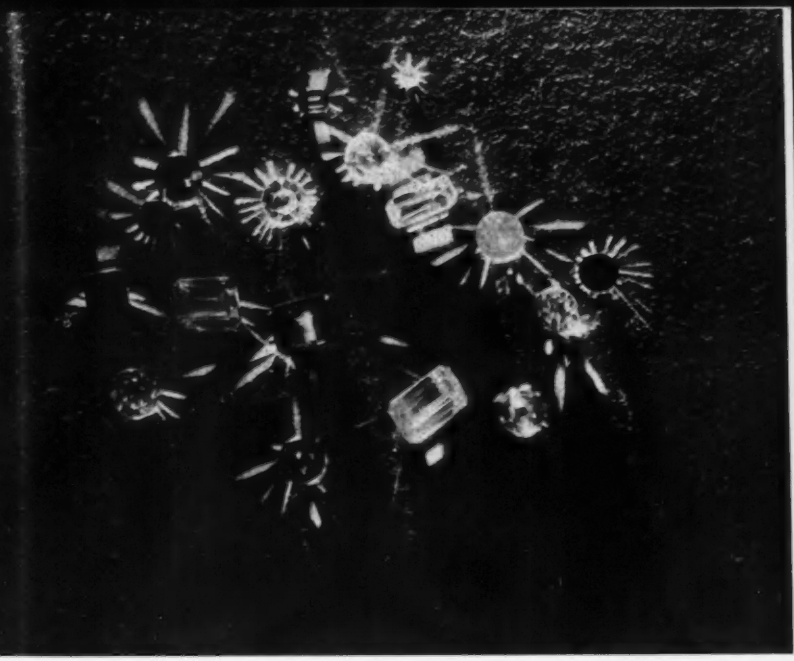
Relative newcomers to the hayfever drugs of the anti-histamine class are Thephorin, described by Dr. C. Lehman of Hoffman-La Roche, Inc., at Nutley, N. J.; Antistine, reported by Dr. Rolf Meier of Ciba, Ltd., and the University of Basle, Switzerland; thenylene or histadyl; Nepera and Rhone Poulenc. All have about the same pattern of action, Dr. Samuel M. Feinberg of Northwestern University Medical School stated.

All, with one exception, are local anesthetics. All show their greatest effect on hives and other forms of itching skin. They are about equally effective in relieving the sneezing and other symptoms of hayfever, including the kind that may come at non-hayfever seasons. None of them is very effective in asthma.

All have about the same undesirable effects, including that of causing sleepiness with lassitude, weakness and inability to concentrate. Dizziness and nervousness are other common undesirable effects.

Curiously, these drugs not only vary somewhat between themselves in their effects, but they also vary in the response of the patient. That is, one with the highest sleepiness effect in general may cause less sleepiness in an individual patient than one that generally causes least sleepiness. The same sort of variation occurs in patients' response to the relief the drugs give.

The drugs are usually given by mouth, but they have been used as aerosols inhaled by asthma patients and in salves for relief of itching skin.



▶ "AND THEY *shall fetch thee jewels from the deep" promised Titania, the Fairy Queen in Shakespeare's "Midsummer Night's Dream." These jewels, newly created by science, are quite worthy of being the fairy's namesake (since they are oxide of titanium), shining "with spangled starlight sheen."*

New Man-Made Gem Sparkles With Brilliance of Diamond

Fairy Jewels Synthesized

▶ TITANIA night stones, a new synthetic gem with a play of colors equal to a fine opal and the fire and brilliance of a diamond, have been developed at the titanium division of the National Lead Company research laboratories, South Amboy, N. J., Dr. Roy Dahlstom, the director, has revealed.

No name has yet been adopted for them either by the laboratory or by Dr. Charles H. Moore who carried out the development. They are true night stones because they are far more brilliant under ordinary electric lamps than under daylight. Their primary use will probably be for ornaments worn with evening gowns, but

they have possible industrial applications.

Titanium is a very plentiful and widely distributed metal, never found free but only in compounds. The principal ones are ilmenite and rutile. Titanium oxide, from these, has become the principal white pigment used in paints. Rutile is used in welding-rod coatings and in alloys and carbides. Pure titanium, now produced experimentally by the U. S. Bureal of Mines, has a promising future as a structural material.

The new gems are cut from boules made of rutile under intense heat in a special automatic equipment developed by Dr. Moore. In this the process differs from the manual operation of the furnaces and burners used for synthetic sapphires and rubies. Under this heat pure rutile is grown into a mass resembling a small icicle, or boule. Boules have been made weighing 125 carats and more.

Truly a new gem, this clear synthetic rutile is in no way an imitation of anything. Rutile found in nature has a red or brown color and the only rarely discovered natural gems of rutile are semi-translucent. These clear transparent rutile gems can be produced in colors ranging from red through yellows to deep blues.

The research, which culminated in the development of these gems, was initiated to determine the true color of rutile. Rutile pigments used to give the brightness and whiteness to paints have a slightly yellow tone. Since no way was found to determine the true color from the small pigment particles, larger pure crystals were required.

Pure rutile crystals may have other uses in addition to that of gems. Industrial uses have not yet been investigated due to the present limited laboratory production. The atomic structure of the mineral indicates the possibilty of excellent electrical, optical and sonic properties.

Dry Cells for Cold Climates

➤ LOW-TEMPERATURE electric dry cells, developed during the war to meet the requirements of Arctic climates by the National Bureau of Standards, will find many uses in all cold countries. Prewar dry cells were of little use at temperatures below zero.

The new cells, of two different types, will give acceptable electric output at temperatures of 22 degrees Fahrenheit below zero and lower, and are operative at minus 40 degrees. Dry cells of the ordinary ammonium chloride type become inoperative at about four degrees below zero.

One of the new cells is designated as the methylamine hydrochloride-ammonium chloride type. The other is a calcium chloride-ammonium chloride type. The second has given outstanding performances and, at present, seems superior to the methylamine hydrochloride type.

Details of the two new cells were given the Electrochemical Society by the three men responsible for their development. They are Earl Otto and George W. Vinal, of the National Bureau of Standards, and C. K. Morehouse, who is now at M.I.T.

For the Home Lab

King Cotton

by BURTON L. HAWK

▶ MORE THAN 20 million Americans depend on cotton for their livelihood, either directly on farms or indirectly from industry. It stands with wheat and corn to form the "Big Three" crops of the United States.

Although grown and used for centuries, cotton really came into its own when the chemist entered the scene. For what he created from cellulose, chief ingredient of cotton, was nothing short of miraculous. No longer used just for fabrics, it now plays a part in the formation of artificial silks, paper, cord and rope, adhesives, explosives, drugs and medicines, plastics, lacquers, photographic film, phonograph records, and a multitude of allied products. The chemist has succeeded in bringing the raising of cotton to an economically sound basis, literally from "poverty to prosperity." He has even utilized the seed. The all-important cottonseed oil is widely used in lard substitutes, in the manufacture of oleomargarine, as a source of glycerin and explosives, in soaps, lubricants, cosmetics, and cooking and salad oils. And to think that the seed of cotton was once a general nuisance—a "waste product."

Pyroxylin

Absorbent cotton is practically pure celulose. Let us examine a few compounds of this important substance.

When cellulose is treated with nitric acid several very useful cellulose nitrates are obtained. The "dinitrate" containing 11% of nitrogen is known as *pyroxylin,* or collodion-cotton.

Pour 3 cc. of water into a beaker and carefully add 15 cc. of sulfuric acid and 6 cc. of nitric acid. Cool the solution by placing the beaker in a larger container of cold water. When thoroughly cooled, add several small clumps of absorbent cotton. Allow the cotton to remain in the solution for about 15 or 20 minutes. (Keep the solution cooled all the while.) Then remove the cotton and wash thoroughly with warm water and allow to dry. Do not heat.

Pyroxylin is highly inflammable as can be demonstrated by bringing a small piece to an open flame, using a crucible tongs of course.

Collodion

Pyroxylin will dissolve in a mixture of alcohol and ether to form a syrupy liquid, *collodion,* which is used in cements, lacquers, etc.

Mix together equal proportions of absolute alcohol and ether. Place a small quantity of dry pyroxylin in the mixture. Stopper and let stand for a few days. At the end of this time, pour off a small quantity of the clear liquid into a watch glass. This is, or should be, collodion. Allow it to evaporate at room temperature. A thin film of pyroxylin remains. The film is waterproof, as can be demonstrated by pouring water into the watch

glass. Pour off the water, and if you are careful, you will be able to pick up the film in one piece with a pair of tongs.

Celluloid

Celluloid is not easily made successfully in the home lab. Commercially it is formed by blending together pyroxylin, camphor and alcohol. By means of hydraulic presses, the mass is pressed together at high temperatures, cooled somewhat, then molded into the desired shape. Because of its high inflammability, celluloid is rapidly being replaced by numerous newer plastics.

Cement

A good "cellulose" cement can be made by dissolving pieces of celluloid in acetone, the thickness of the cement depending upon the concentration of the solution.

Gun-Cotton

The nitrate of cellulose containing 13% or more of nitrogen is known as *gun-cotton*. ("trinitrate").

Carefully mix together 5 cc. of con. sulfuric acid and 6 cc. of con. nitric acid. Cool the solution; then place a small piece of cotton in it for 10 minutes. Remove the cotton and wash thoroughly with warm water. Allow to dry at room temperature. When dry, bring the cotton to a flame. Note the brilliant flash as it burns rapidly. Gun-cotton is used in producing smokeless powders, dynamite, cordite, and other explosives.

Remember, you are working with caustic acids and inflammable compounds. Use only small quantities and work carefully.

Cotton: Future

The scientist is a restless creature. He creates a useful substance. But he is never satisfied. His previous creation is never good enough, and he finds himself forming new and better things today to replace those he produced yesterday.

Rayon is an extremely useful article. But consider nylon. Here is a serious competitor—better, stronger, more versatile—and no doubt it will entirely replace rayon in years to come.

Celluloid, as a plastic, already is a thing of the past. Consider Lucite, Plexiglas, Vinylite, etc.—all up and coming plastics with many advantages over celluloid. Finally, consider soy-bean oil, another competitor of cottonseed oil.

Could the same scientist who brought cotton to the throne contribute to its downfall? For already we are beginning to realize that cotton is no longer king!

New White Finish

▶ INDUSTRY now has a new kind of glistening white finish to apply to all sorts of surfaces. It is a heat resistant paint that has properties between those of baked enamel coatings and ordinary paints.

A new silicone resin that becomes hard and durable under the influence of heat has been developed by the Dow Corning Corporation during the course of experimentation upon the unusual war-born compounds made from sand, coal, oil and brine.

Thousands of High School Seniors Prepare for Science Talent Search

Young Scientists Compete

➤ RECRUITING for leadership in the army of scientists who have come to be America's greatest hope in peace and surest shield in war is actively under way again, with the formal announcement of the Seventh Annual Science Talent Search.

Forty thousand principals and science teachers, in every public, parochial and private high school in the United States, have received full details concerning this competition for $11,000 in scholarships plus 40 all-expense trips to Washington, which will be awarded to outstanding seniors late this winter. Funds for the search, made available by the Westinghouse Educational Foundation, are administered by Science Service through Science Clubs of America.

A great many science-minded students will not need to be told of the new Science Talent Search. During the six years of its existence, it has come to be a nationally known event in the scholastic world, and promising science students begin pointing up for it months, even a couple of years, in advance. They carry on their individual research projects at school or in basement or garage laboratories at home, or in the fields and woods where they go to study trees and wildflowers, birds and insects. They talk over the tough spots with fellow students in science clubs or with sympathetic faculty advisers.

A Science Talent Search is a kind of academic hurdle-race—with each hurdle higher and harder to clear than the one before it.

To begin with, the contestant has to have a good school record behind him, for a full set of his grades, together with statements by his principal or the teachers who know most about him, go to the judges along with his examination papers and essay. While no student is barred from competing, as a practical matter only seniors who are well toward the tops of their classes are likely to qualify for the finals.

Each student must complete a three-hour science aptitude examination in his own school. This is designed primarily to demonstrate his ability to master new and unfamiliar matter, and to reason out correct conclusions from clearly stated though somewhat difficult facts, rather than to find out what he has already learned or memorized.

The contestant must submit an essay of about 1,000 words on "My Science Project." This is expected to be a report on a definite project in laboratory research or field study carried on independently by the student himself.

When the judges have these three things from each entrant — student record, aptitude examination, and essay—they begin the difficult task of sifting. From the approximately 16,000 entrants, a list of 300 Honor-

able Mentions is first selected. These are recommended to colleges, universities and technical schools for scholarship consideration.

Then the student's ability to work and think for himself, as evidenced by his essay on his research project, is brought into the picture, and becomes an important factor in the selection of the 40 finalists who win the all-expense five-day trips to Washington.

Arriving in Washington about the end of February, they will participate in a Science Talent Institute, where they will meet leaders in American science and hear from them of newest research advances.

During their five days in Washington, the 40 finalists will be personally interviewed by a judging committee to determine their eligibility for the Westinghouse Science Scholarships which total $11,000. One boy and one girl will each receive $2,400 Westinghouse Grand Science Scholarships ($600 per year for four years). Eight other contestants will receive four-year scholarships of $400 each ($100 per year for four years). Additional scholarships totalling $3,000 may be awarded at the discretion of the judges, who are Dr. Harlow Shapley, Director, Harvard College Observatory; Dr. Harold A. Edgerton and Dr. Steuart Henderson Britt, New York City psychologists, and Dr. Rex E. Buxton, Washington psychiatrist. Drs. Edgerton and Britt are also the designers of the science aptitude examination.

Primary objectives of the Science Talent Search, as stated by Watson Davis, Director of Science Service, are:

1. "To discover and foster the education of boys and girls whose scientific skill, talent and ability indicate potential creative originality and warrant scholarships for their development.

2. "To focus the attention of large numbers of scientifically gifted youths on the need for perfecting scientific and research skill and knowledge so that they can increase their capacities for contributing to the rehabilitation of a war-dislocated world and to help the United States, with the aid of science, to lead the world to permanent peace.

3. "To help make the American public aware of the varied and vital role science plays in world affairs and in raising the standard of living."

Since 1942 a total of 240 young scientists have been named as winners of trips to the Science Talent Institute. Among this select group of 61 women and 179 men are 11 who have finished college and are now employed full time as chemists, engineers, psychologists, and research assistants in industrial laboratories and as graduate assistants in colleges and universities.

Among those in the first two groups chosen there are now 44 with at least one college degree and of these at least a half dozen hold their second degrees. A few will be Ph.D.'s and M.D.'s early this fall.

All of the previous winners are now in school with the exception of those working or still in service. Among them are engineers, physicists, chemists, medical students, mathematicians, psychologists, biochemists, astronomers and zoologists finishing their training to be ready to contribute

even more than now to their field of science.

Paralleling the national science talent search, there will also be a number of state science talent searches. In those states all students entering the national search are automatically entered also in the state search. Last year there were state science talent searches in Georgia, Louisiana, Illinois, Iowa, Tennessee and Virginia; this year there will probably be additions to the list. Winners of the state science talent searches are given recognitions of various kinds, including honorary memberships in State Academies and the American Association for the Advancement of Science, and such substantial awards as full-tuition scholarships in colleges and universities in the respective states.

Complete details of the Seventh Annual Science Talent Search can be obtained by writing to Science Clubs of America, 1719 N St., N. W., Washington 6, D.C.

Soybean Replaces Linseed Oil

➤ LINSEED oil has a new rival in the paint field. It is a chemically treated soybean oil which has similar drying qualities. Linseed oil, for many years, has been the base for paints and linoleum.

The discovery of this process of treating soybean oil to make it suitable for use in paints will free America from reliance on imports of linseed oil, or the flaxseed from which it is obtained.

Dr. Alexander Schwarcman of Buffalo has reported in a paper of the American Chemical Society that the United States, now producing annually over 1,000,000,000 pounds of soybean oil, can produce as much as needed to supply the demands of this new use.

Castor oil also can now be used in paints, as a substitute for tung oil, most of which is imported. It must be first treated, however. The treatment process is a dehydration that causes the castor oil to have fine drying properties.

About a billion pounds of linseed oil are consumed annually in the United States, one-half of which is imported, mostly from Argentine. It is used entirely for paint, varnishes, linoleum, and allied products. Castor oil is used in a great variety of industries, mostly for textiles, wall sprays, lacquers and artificial leathers. Most of the castor oil used is extracted from Brazilian castor beans.

The United States consumes each year in foods and in industrial processes about 6,000,000,000 pounds of vegetable oils, and about 6,000,000,000 pounds of animal fats, two-thirds of the latter being butter and lard. In addition, an unknown amount of fat is consumed as food in eggs, meats and plants.

The three principal uses of oils and fats are for food, soap, and paints and allied industries. Approximately two-thirds is used for edible purposes, one-fifth for soap, and 8% the third purpose.

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